MECHANISED MINING AT A SEMI-STEEP DIP.

Thomas van den Berg

BTech Mining Engineering , NHD Metalliferous mining (TWR)

Business Area Manager-Central Section, Amandelbult Section , Anglo Platinum

SYNOPSIS

Mining a 1.3m UG2 reef, semi-to steeply dipping (18-20 degrees) using mobile machinery traveling on apparent dips (9-12 degrees), using throw blasting and smart bolting as support.

Location

The room and pillar projects are situated on Amandelbult Section, Anglo Platinum, on the Ug2 at a head grade of 4.37g/ton, one below the Bierspruit river (8WTM3) and the other on the Eastern section at 43E (43ETM3).

Why room and pillar?

The 8W area has restricted panel lengths due to the 100-year flood line of the Bierspruit whilst the East section has rolling reef with poor hanging wall conditions. Increasing Amandelbult's tonnage capacity with a faster ramp up, using mechanised mining methods. Improving the safety of workers, whilst using a higher skilled workforce within a modernised, and worker friendly mining method. Reducing mining costs in a commodity market where we remain price takers in a volume driven industry. Utilising narrow seam machinery, with improved safety and labour efficiencies. The incorporation of long hole drilling, smart bolting, supplier maintenance contract, rock on floor contract, and using throw blasting, all within a semi-steeply dipping mechanised room and pillar section.

Mining Method

Drive four declines down at a 9-degree dip; the middle declines for ingress and egress, including a hanging wall belt, and with all infra-structural services. The outer declines serve as ledging declines, where panels are at 5 degrees above strike, and the footwall on an apparent dip of 12 degrees. The intention is that stope drives will be driven ahead, with follow behind 4m long-hole drilling taking place from the drive into the stoping block. Vent holing's will have been blasted between panels during development, stoping will then be throw blasted into the roadways. Pillars will then be created at a normal 1.3m-stope width with improved strength using the squat pillar formula. The installation of roof bolt support takes place in roadways during their development, using spin to stall technology, extensometers and telltales. Stoping areas will be no go areas, once roadways have been long-hole blasted and cleaned. The roadways will be LHD cleaned, thereafter water jetting will occur on the stope footwall, and then retreat vamping. Ore will be transported by LHD's to a fishbone belt system, the ore is then moved from within 150m of the face on the belt to the surface silo. Dilution will have to be well controlled, as at 7% there is already value loss compared to conventional stoping.

Efficiencies and costs

An LP Aardmaster drill rig should deliver 20 000 tons, with three LP 4.2 Aardvarks supporting it. Employee efficiencies are expected to be a minimum of 500 tons per total employee costed per month. Costs are expected to be as follows: Shaft head R65/ton, cash cost R133/ton as at (08/2000).

Equipment selection

Boart Longyear have been chosen as the preferred supplier, at the outset of the project they were the only supplier with proven low profile LHD’s in the market. These machines were seen in operation at various operations with varying success. They had the capability to supply a full fleet of equipment, which lent itself well to a maintenance repair contract. Their pricing was also competitive and they have delivered all machines according to schedule.

Future Frontiers and Conclusion

To prove the viability of Amandelbult’s room and pillar mining using the above method, whilst setting a benchmark for the industry to compete against. The pilot project at 8W, has been operating for almost 18 months, to date we have still not achieved our target of 25 000 tons per month, the main reason being the infrastructure which is lagging behind schedule. The machines are operating well; the throw blasting and long hole stoping are working but require more fine-tuning. We believe the project has huge potential, and we intend in due course to prove this, the greatest test is going to be dilution control and in five years from the start of the project, when the project will be reviewed in terms of replacing the fleet. The challenge will be ensuring that we fill the belts/ shafts with quality platinum bearing rock.

Our slogan on Amandelbult is, “At Amandelbult we make everything work! “, and we hope to hold true to it.

INTRODUCTION

Anglo Platinum has recently embarked upon an expansion program (2000), to ensure that it remains at the forefront in terms of costs, and volumes. The market forecast remains currently that demand exceeds supply, and to ensure that this gap is filled Anglo Platinum will continue to expand, to ensure it remains a low cost producer. At the same time the company has been busy with Project Breakthrough, a portion of breakthrough is mechanisation. Mechanisation consists of various thrusts, and one of these is Room and Pillar mining. The company intends seeking for new methods of mining, to ensure that safety and costs are enhanced. Amandelbult section is one of several mines within Anglo Platinum; Amandelbult is situated in the Limpopo province, approximately 35km from Thabazimbi and 75km from Sun City.

The mine produces approximately 650 000 tons per month, employs a total of 10 000 employees, including contractors, currently the mine is one of the lowest cost producers in the Platinum industry.

The mine contributes a significant portion towards Anglo Platinum's profit, approximately 43% (2001), to ensure it remains in this position it will be required to continue to increase its volumes, whilst reducing its costs.

Plate 1 Amandelbult 1 #, at sunset.

The mine currently produces 340 000 tons of Merensky ore per month, 240 000 tons of UG2 per month, and 60 000 tons of UG2 Opencast. UG2 outcrops may still be mined from surface, and thus mechanised operations have been embarked upon in two different areas of the mine. The mine's ore body does not lend itself to Conventional Trackless Mining, as it dips at between 18-30 degrees, thus an innovative mining method had to be developed to attempt trackless mining in these challenging conditions. Currently (2002) both Mechanised operations are in a build up phase, with the 16W area planned to produce 60 000 tons per month and the 43E area planned to produce 60 000 tons per month as well. The intention is that both sections should deliver 120 000 tons per month by the end of 2003.

The intention of this paper is not to give one a scientific thesis, but rather an understanding of the principles that were used in designing the operations. The proof of the pudding is in the eating, and Amandelbult will only be able to relate the actual successes at a later date.

WHERE DID IT ALL BEGIN

- Anglo Platinum were embarking upon their Mechanisation drive, in an endeavor to counter allot of issues were identified in their S.W.O.T. analysis. Thus looking at smarter ways of mining was on the agenda.
- Contingent of Anglo Platinum employees went overseas, to look at various technologies being applied to a similar mining ore body. The group visited the main suppliers who were looking at various means to mine narrow seam tabular ore bodies. The Group also visited Polkawice in Poland and Sorigov in Russia, where the technology's were viewed in a working mine.
- The Amandelbult management team then visited, various mines both within the group and external to the group where similar mechanized mining was taking place, this included visits to the coal and chrome mines in South Africa.
- After attending a supplier technology review, the Business Manager Mr. F.A. Uys recommended that we look at a combination of room and pillar with long hole stoping, and thus as a team, the current layout was birthed.
- Once the layout was in place, we looked at opencast methods of mining, and attempted to incorporate some of their principles underground. Issues like blasting once a week, a rock on floor explosives contract and also throw blasting. No physically intensive use of labour, but rather all done by machine.
- The support method had to be unique to the mine, as we were aiming at minimum material and transport, but having a stiff support system, which would all be installed by machine. Thus we decided upon the Smart bolting technique.
- Due to the 100-year flood line, the existing 16W reef decline was decided upon to be the pilot site, to trial and attempt the mining method.

ORE BODY

The current UG2 ore body has the following characteristics on Amandelbult:

- Average Stope width 1.3m
- Dip of reef: 18-20 degrees

The UG2 reef tends to be consistent, extensive geological information is available regarding the UG2 due to the Merensky mining, which has already occurred.

General Geology and structure

The UG2-horizon consists of a main chromitite layer (60-80cm) overlaid by two or three "leader" seams, each averaging 11cm in thickness. The poikilitic pyroxenite (interstitial waste) interlayered with the chromitite normally contains lenses and grains of chromitite. The immediate footwall of the UG2 is a pegmatoidal feldspathic pyroxenite (similar to the Merensky Reef), which varies in thickness from 0 – 70cm. The hanging wall of the UG2 is usually harzburgite, 50-80cm thick. The harzburgite grades upward into poikilitic pyroxenite. Within this pyroxenite, a thin ±1cm wide, distinct Cr-seam, occurs. This Cr seam situated between 80 – 150cm above the UG2, together with the harzburgite, constitutes a hanging wall hazard especially when exposed during mining.

A composite dyke/fault zone separates the western block (A) from the eastern block (B), with a total up throw to the east of approximately 20-30m. This fault zone has previously caused bad ground conditions on the Merensky horizon, and could conceivably interfere with mining and development on the edges of Blocks A and B (Plate 3).

Another fault zone lies between Blocks B and C (Plate 3); the total throw on this is approximately 30m, down on the eastern side.

Although some Merensky mining actually took place within these fault zones, it is not included in the present reserves. However, the decline development will pass through the fault zones and if ground conditions permit, the reef will be extracted.

Within Blocks A and B, there are no significant known disturbances, apart from two small reverse faults and a drilled/mapped-indicated slump in Block A (Plate 3). A few minor UG2-slumps and potholes, catered for by the 13% geological loss, can be expected. The reef horizon is generally quite stable, but undulations ("rolling") and minor strike changes do occur in places. This is clear from haulage and crosscut mapping along the original Merensky development ends. Some dip changes also occur, varying from 17° to as steep as 24°, but the average appears to be 19° to 20°. Plate 2 depicts a 3D model of the ore block.

Adequate UG2-intersections (Plate 3 – Structural Data) exist to verify the presence of UG2-reef right through these blocks with a high degree of confidence. The geological loss over the whole area is estimated between 10 and 13%.

Plate 2- 3D drilling model of block A

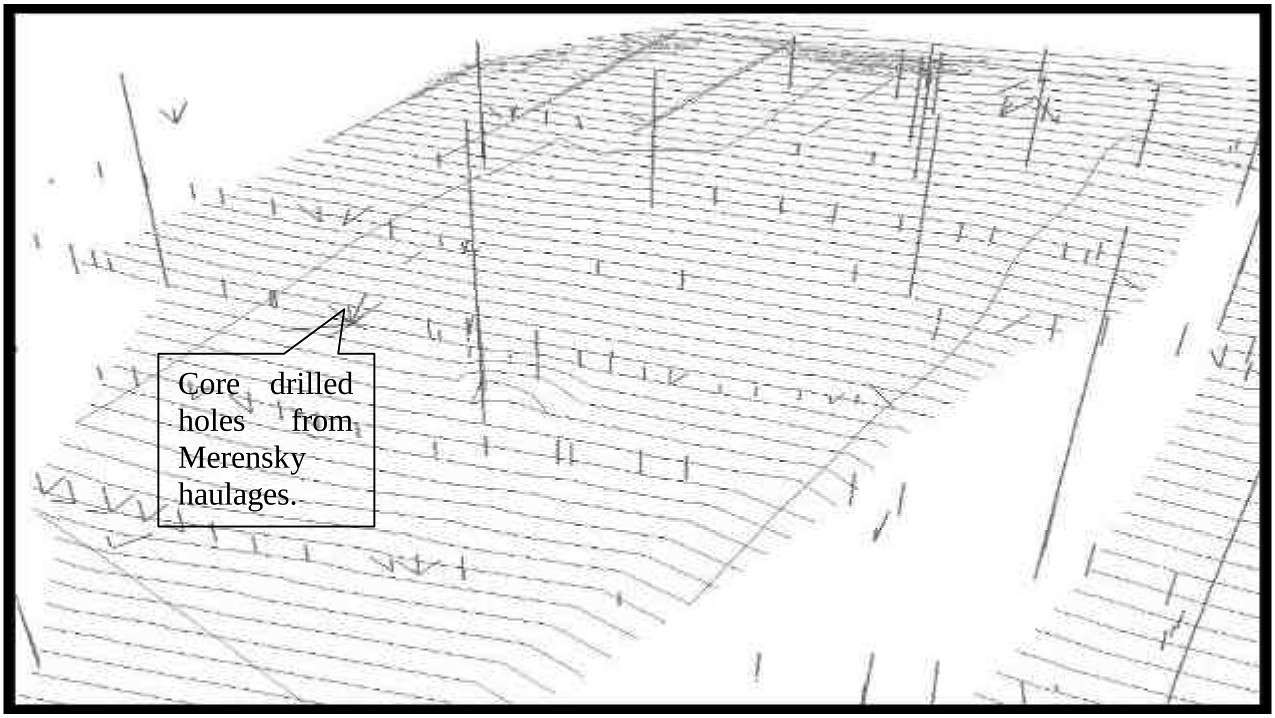
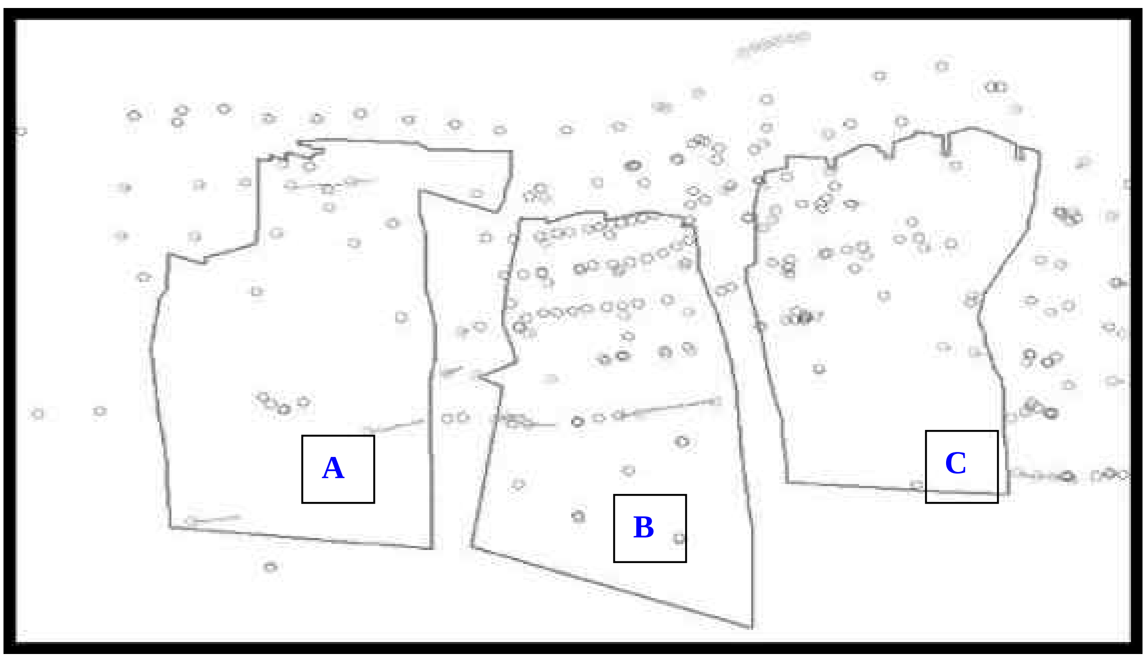


Plate 3-Structural data incl. borehole and mapped intersections of the UG2 Reef.

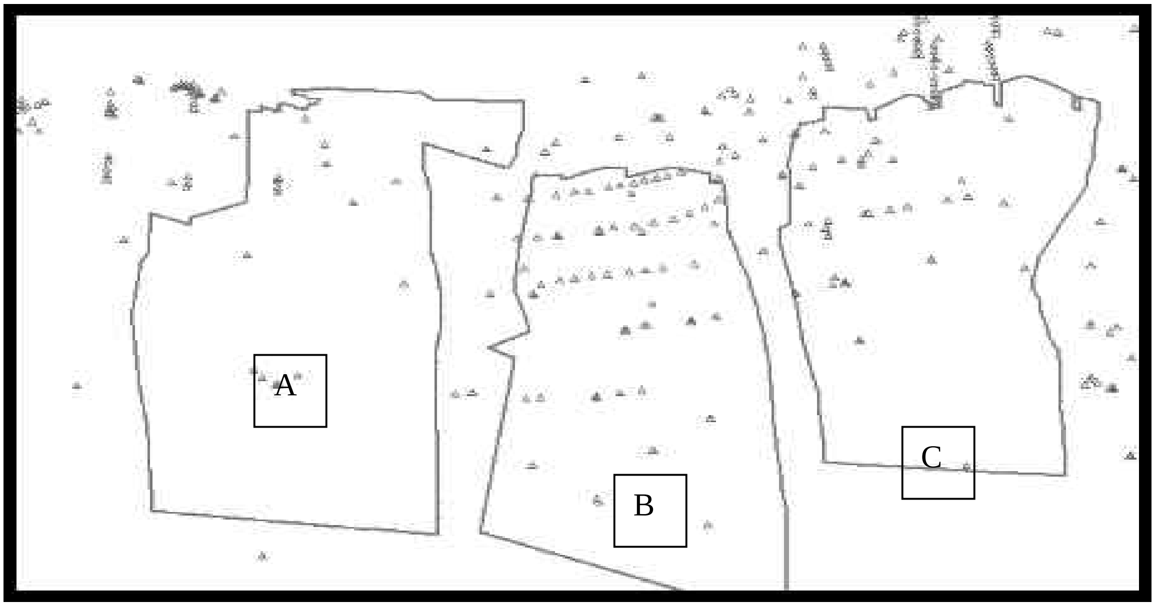


Sufficient intersections of the UG2 Reef exist to classify this ore body as a proven reserve. No insurmountable structural problems exist. Areas of concern include unfavorable ground conditions close to the fault zones as well as some degree of undulation along the reef horizon. The narrower reef widths in certain areas will cause excessive dilution in the development ends and will have an adverse effect on the grade.

Grades and reef widths

Plate 4 depicts the borehole and underground sampling used to create kriged grade and reef width block models in Data mine. These models are depicted in Plates 5, 6 and 7.

Plate 4-Sampling data, from boreholes and reef intersections.



<u>Plate 5</u> (PRP0000) shows the **<u>Kriged reef widths</u>**, with a clear narrowing (roughly parallel to strike) of the UG2 along the center portions of both Blocks A and B. In these areas, one could expect to mine reef as narrow as 1.2m (or even less). ***This will cause dilution problems and consequently low head grades, due to the minimum development specifications.*** **Block A average width: 1.31m. Block B average width: 1.33m**

Plate 5-Kriged Reef Width (m)

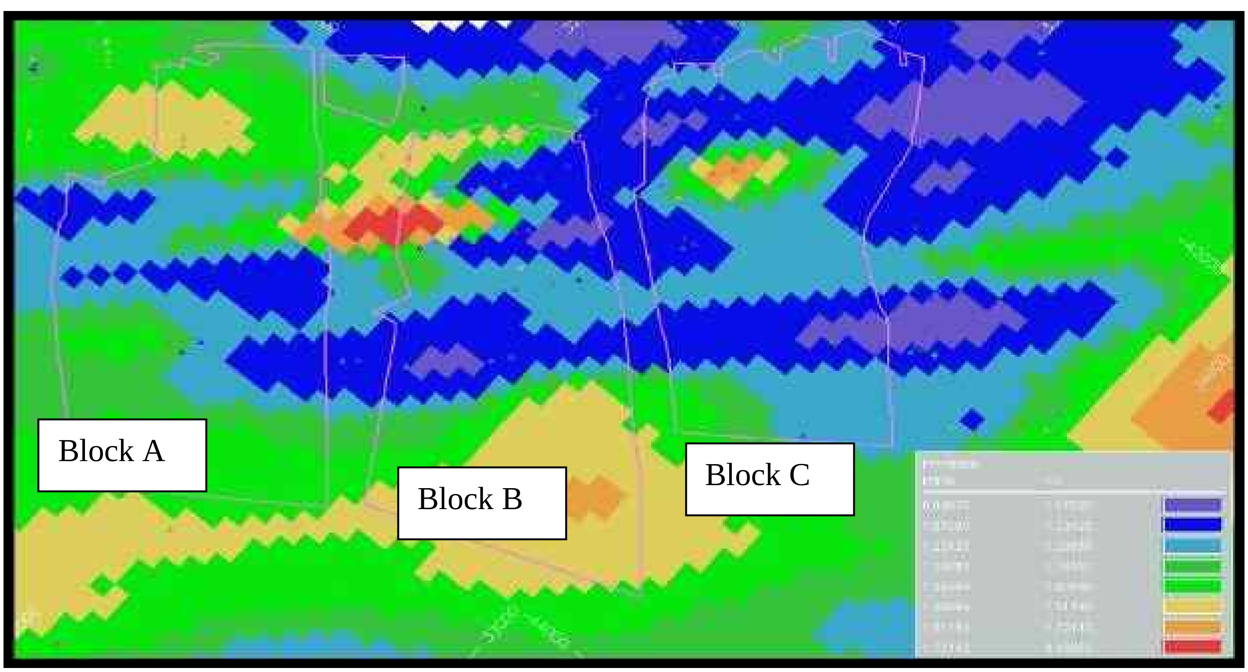


Plate 6 (PGE0000) shows the undiluted **reef value distribution** (4Element, in g/t). The higher values (4.7 to 5.6g/t) occur mostly in the northern portions of the blocks, tapering off to between 4.2 and 5.2g/t in the southern portions. Block A average grade: 5.02g/t. Block B average grade: 4.74g/t. (Note: These figures are for the reef only, dilution due to the development and mining parameters are not included).

Plate 6- 4E grade (g/t)

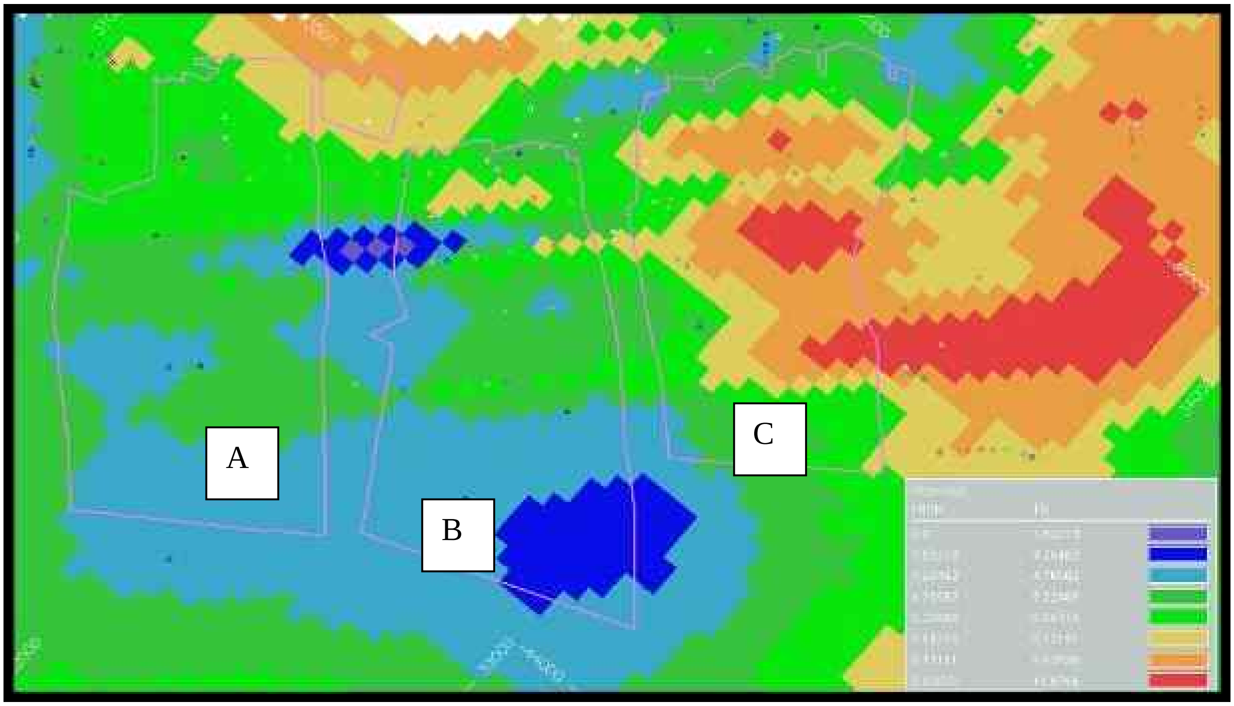
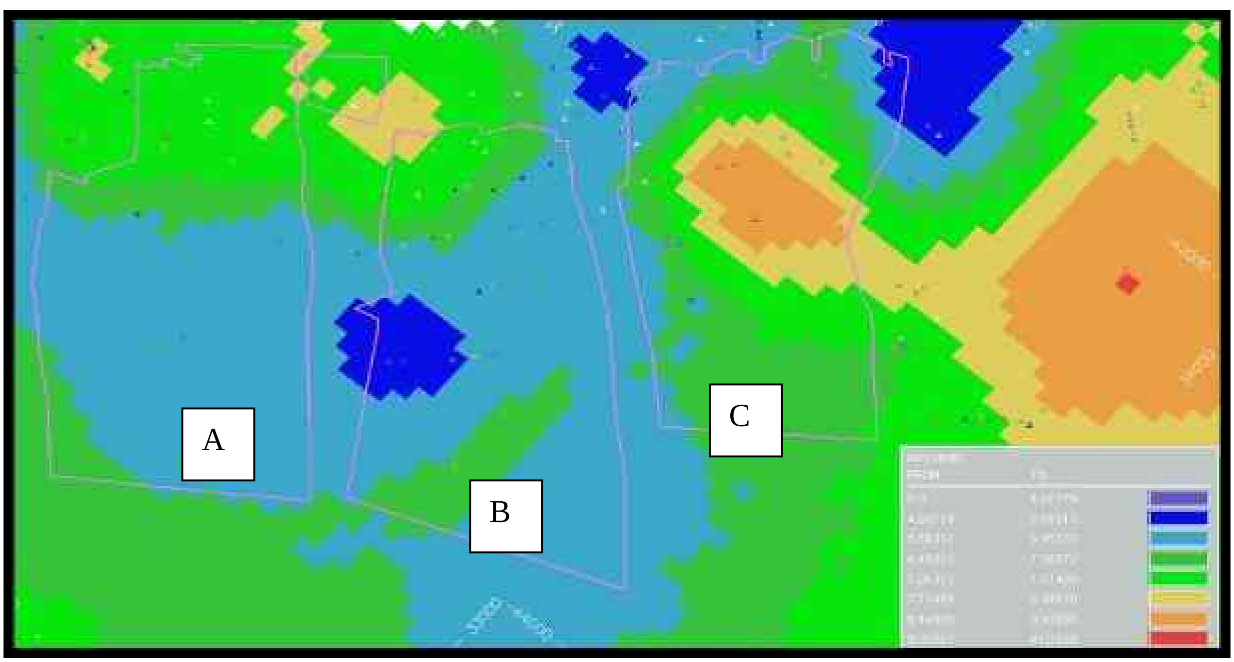


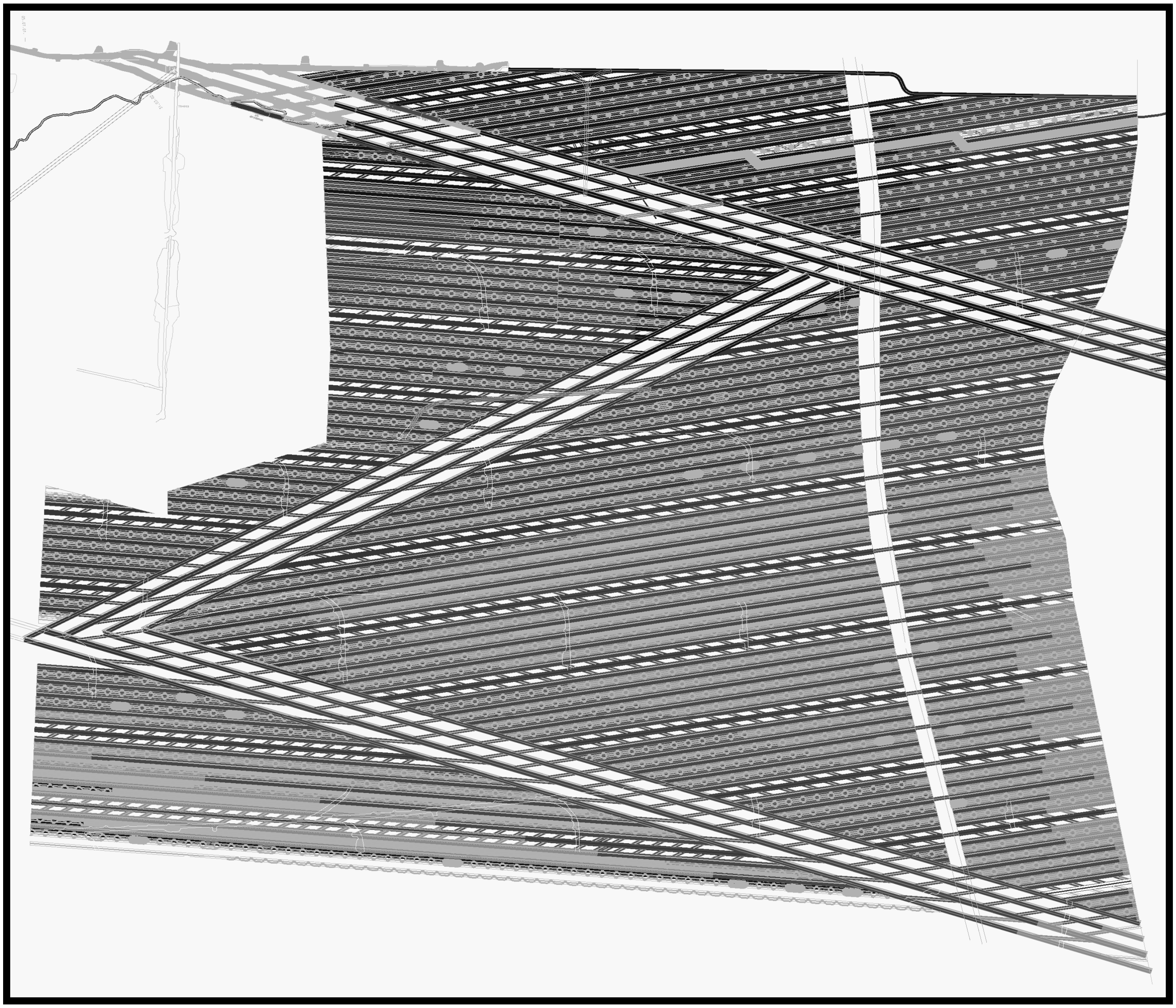
Plate 7 **(ACC0000) shows the** Kriged 4Element Content **(m.g /t).**



Location

The room and pillar projects are situated on the Amandelbult lease area, on the Ug2 reef horizon, at a head grade of 4.37g/ton, one below the Bierspruit river (8WTM3) and the other on the Eastern section at 43E (43ETM3).

Plate 8 Five year plan and layout of 16W area, at 60 000 tons per month.



WHY MECHANISED/ROOM AND PILLAR?

A motivating factor is that there is reduced risk in terms of people's safety; this though is not the major motivating factor. The fact that employees are under the protection of canopies, and that less people are employed, reduces the risk exposure.

Revenue can also be produced from the initial outset as all development is on reef. The cost per ton mined is reduced, as a large portion fixed costs is reduced in employing less labour, but the cost per ounce is detrimentally affected due to dilution.

The requirement to rejuvenate productivity also motivated that alternate mining methods were looked at. The recent improved low profile technology also assisted in making the decision to attempt a mechanized project.

The 8W area has **restricted panel lengths** due to the 100-year flood line of the Bierspruit whilst the East section has rolling reef with poor hanging wall conditions. Both sections **require an alternative mining method**; access to the ore body is available from the outcrop, or 30m below the surface.

Increasing Amandelbult's tonnage capacity with a **low capital input**, when compared to sinking a new shaft (R1Billlion plus), the capital employed is relatively low. The initial purchase of machines, was approximately R15M for a fleet which has the capability of producing 25 000 tons per month, this equates to cost of R10 per ton over the life of five years, with no cumulative interest included. The total cost though can become more, if correct maintenance and damage control are not enforced. It is also imperative to ensure that total cost is looked at over the life of the project, as the machines will require replacement. The current fleets are planned to be replaced every five years, to ensure they remain cost effective, with high availability and do not adversely effect revenue generation. The total cost of the Capital was in the region of R50M (2000). The above capital is purely a shaft head capital cost. The payback on the capital expended is within a year, and thus makes an excellent business case, even though it is more expensive per ounce than conventional mining, conventional mining would have a much longer payback period as it involves extensive development, which can range anything between 2 years to seven years, depending on the development required.

Faster ramp up to increased production, as the declines are put down on reef, and there is **no waste development,** shafts or belts are used only to generate reef tonnage, thus no infrastructure hoisting time is wasted moving waste. This allows almost immediate revenue generation, thus the **capital employed starts paying itself back almost immediately** and breakeven point is reached within a much shorter space of time. My brief calculations indicate that at the current Platinum price of $500+, the projects should pay themselves off within the first year, if the required levels of production are achieved. Thus the **break-even point is achieved** within the first year of operation. The **development is all revenue generating** and thus allows a faster build up to production as more of the ore body is opened up. Ore reserves though are not proven, and it is critical that if no knowledge exists of the ore body ahead of the declines, that an extensive pro-active drilling program exists. **Extensive knowledge of the ore body existed** as the Merensky reef had already been mined out, and the Ug2 had been mapped from Merensky haulage's, crosscuts and drilling.

SAFETY

Improving the safety of workers, although the amount of injuries and risk exposure is vastly reduced. The injury frequency rates remain consistent with conventional mining as less people are employed, thus when an injury occurs it impacts injury frequency rates with a greater effect. The severity of injuries also tends to increase, as when an injury or contact takes place-involving machines, it results in severe contusions, fractures or loss of life. It is thus important to limit the amount of people on foot in the machine areas, as visibility is vastly reduced in low profile machines.

Methods of managing the interaction of men and machines include:

- Minimise and if possible have no persons on foot.
- P.D.S.—Personnel Detection Systems on the machines.
- Camera and screens, which indicate blind spot views to the driver.
- Barriers in Declines and roadways.
- Pedestrians are always to remain in full view of the driver, and only pass the driver side.
- People should never work or walk on the down dip side of machines.
- The use of reflective clothing and hardhat stickers.
- Drivers are always to park their machines in the direction of travel, once restarting the machine.
- Never pass under a boom or bucket whilst raised.
- Use of personnel carriers and deliver the operator, to the machine.

Important factors to concentrate on with regard to safety in trackless mining are:

Respect and Discipline, trackless mining involves using heavy machinery, which is operated by men, who are known to take shortcuts, be it due to work pressure or personal motivation. It is vital that all staff is consistently made aware by management, that unsafe behaviour will not be tolerated. In trackless areas in general there are not many unsafe conditions, most operations have all their drivers/ operators, in canopies and strapped in with seat belts. The biggest reason for injuries and fatalities in trackless areas is the behaviour of the operators. Operating heavy machines in confined areas is not an easy task. The drivers continually have to be aware of their surroundings and limitations of their machines. Generally respect for the machinery is not always appreciated, the operators operate the machines at higher speed than is allowed, especially when management visibility is low. The operators also constantly have to be checked for alcohol and drug use, one cannot afford to have drivers whose concentration is lacking in these confined areas. Pedestrians and persons who illegally ride on the machines are also a constant hazard. Thus operator discipline must of the highest possible.

Repairs and maintenance, it is imperative to ensure that all systems and safety devices on machines are continually maintained and recorded. When investigations take place after an incident it is too late to improve the above, thus to remain pro-active in terms of safety, one must do the upfront work. Maintenance to all critical linkages, pins, braking systems, fail to safe systems, fire suppression, and axles is of utmost importance, it is important to have a maintenance system, that identifies and highlights these ahead of failure. Brake tests and emergency preparedness are important to ensure operators know how to react in case of failures and emergencies.

Rubber tyre's, flat tyres on dips place the machine and operator at high risk. The tyre condition is very much a key factor in terms of productivity and safety. The majority of tyres in Amandelbult 's areas have been foam filled to ensure that sidewall cuts, do not adversely affect productivity or the stability of the machines. Since the inception of foam filling the downtime has decreased (more on this is available under Efficiency and costs). The foam filling also allows you to continue using a tyre until destruction, even if it has a side wall cut, which if the tyre was filled with air, it would have to be immediately removed. The harsh conditions of the sidewalls due to the dip, necessitates the use of foam filling. The other safety advantage is that the lock ring risk is negated, thus it is safe to handle and use the tyre. Most manufacturers of axles are not favourable with the use of foam filling due to the extra weight and spin generated on the axle. Kessler though do not have a concern, with foam filling.

Roof bolts, as they are the only means of support in conjunction with pillars. The effectiveness of the resin has always been questioned due to over and under spinning, allot of these issues are resolved with spin to stall techniques. As the manager you are responsible to design, approve and ensure that the support system adequately and systematically supports the hanging wall, thus it is imperative that you have a reliable support system.

Roadway conditions determine driving practices and also result in excessive wear on tear on the machines. Roadways, which are uneven, have rocks on them, are potholed and have excess water on them, result in the driver battling to drive effectively and may result in loss of control over the vehicle. The driver is also negatively affected as he is shaken about in the drivers seat, resulting in kidney problems. It is important to have the correct dimensions blasted underground, to ensure that machines can maneuver easily, that the correct clearances are adhered to, and that no blind corners are created. The dip of roadways is also critical, as when the dip is to steep, it results in the machines running on their brakes continually, also when they encounter apparent dips which are too steep, they slide sideways and get stuck. People should never be allowed to work on the down dip side of machines.

Recirculation, engine exhaust fumes result in noxious and poisonous fumes, heat build up can also effect the concentration of workers as well as the effectiveness of machines. In mines where radiation exists, recirculation also results in the build up of radon daughters, which is detrimental to the health of your workers. Where methane occurs, recirculation will also result in the methane increasing in concentration leading to an explosion with disastrous results. Monthly noxious fumes survey as required by the law, Generally re-circulation also results in poor visibility and excessive diesel soot. Would you start your car in the garage, and then wonder if noxious fumes will overcome you? Only those set on suicide attempt this!

Fires and fire suppression systems, should a machine catch on fire, it has serious implications for the health of the workers, as the air will be severely contaminated with poisonous and noxious fumes. Thus it is an essential to have excellent fire suppression systems on board. More importantly though, is that these systems are correctly maintained and kept in working order as they face quite severe punishment, being on board the machines. The workers must also all be issued with self-contained respirators, to enable them to reach a place of safety and fresh air point.

Amandelbult 4. L.I.F.E.

A safety system that Amandelbult has put in place recently is known as **" Amandelbult-4 LIFE"**, the essence of this system, is that we as members of Amandelbult all actively care for one another, and that we regard life as valuable and precious. Something that should be nurtured and cared for as one would a garden. The system is timeless and as it is based on principles, thus it will still be applicable in many years to come.

The system comprises of the following:

*The **4 elements** of the safety*

> **Planned inspections**- continually inspecting and over inspecting critical areas/ machinery. You get what you inspect, not what you expect! Over inspection being the principle issue at hand. Peer audits are also done twice a year in all the workings, to assist in identifying hazards and high-risk areas.
>
> **Planned task observations**- continually evaluating the way and means, which we do, tasks, thus ensuring that our training, standards, procedures and lesson plans are still applicable.
>
> **Group meetings**, to ensure that the correct issues of relevance are communicated and that our employees have the correct channels available to them to communicate any concerns they have in terms of safety and health.
>
> **Incident and injury investigations**, it is important that supervisors recognise and address hazards before they become dangerous. Thus an extensive incident reporting system is driven, incidents are analysed and pro- active steps are taken to stop injuries happening. Should serious incidents and injuries take place, an extensive investigation occurs to ensure that a re occurrence does not take place.

<u>Lead by example,</u> it is imperative that management and supervisors set the right climate, have the correct attitude and set the example to sub-ordinates. We cannot expect our workers to work safely and have the correct attitude to safety when we as managers display the incorrect behaviour and attitude. The majority of injuries can also be traced back to our supervision, if we are honest about it. The principle supporting all of this is, the standard you accept is the standard you get, be it the conditions in the workplace or the behaviour of the workforce.

<u>Implement zero tolerance,</u> the implementation of zero tolerance will never stop! The day we think we have implemented zero tolerance will be the day all our safety systems fail. Zero tolerance has been with us ever since mankind became conscious of his conscience, and it will remain with us as long as we have a conscience. The fact that we care for life means that we should never stop implementing zero tolerance. It comes back to the above-mentioned statement, “the standard and behaviour you accept, is that which you will receive”. This though is not all negative, if we remember that discipline should be more positive than negative. What do you remember more from your upbringing and formative years, the times you were rewarded for doing something right or the times that you were punished for failure? Usually we first remember the rewards, and we even brag about them. Thus it is important to catch people doing things right and reward them, but also to discipline those continually failing to adhere.

<u>Friendly and practicable standards,</u> through best practice sessions and revision of the standards, the mine is busy continually challenging the standards and procedures, ensuring that standards remain applicable. That all standards can be complied to, and are not so arduous that nobody even attempts to comply with them.

<u>Eliminate at risk behaviour,</u> the mine has embarked upon a system to reduce at risk behaviour. This will and is being achieved, by changing the mindsets of managers, supervisors and workers, of crucial importance though is to start with senior management. Upon analysis of our injuries, it was found that the majority of our injuries were due to the unsafe behaviour of the injured. Thus a Behaviour Based Safety department has been established, which will put a process in place, of peers observing peers, and steering committees chaired by employees, who will direct and assist with the reduction at risk behaviour. Statistically it has been proven that as at risk behaviour reduces, so injuries and injury rates reduce.

DILUTION

Dilution must be carefully considered, as the room and pillar operations may become revenue consumers if dilution is not properly managed. The current conventional stoping areas in the 16W area has a higher dilution percentage due to the restricted panel lengths, and thus the room and pillar of 16W compares favourably to conventional mining in this specific area. The dilution of the room and pillar operations is higher though than the average conventional stopes and to ensure the sustainability of room and pillar operations, it is critical to control dilution, as well as embark on some reef sorting method. Currently Anglo Platinum is busy with research into reef sorting and showing some favourable progress. One of the major reasons for low profile trackless machinery, is purely due to the narrow tabular ore bodies found in South Africa, previously large tall machines were pushed into narrow ore bodies with minimal success, the outcome was that manufacturers had to go back to the drawing board and redesign their machines to fit into these narrow tabular ore bodies. The advent of CAD, has significantly assisted in this process, as designers are able to redesign machines with far greater ease, machines can now be reconfigured to enable them to be reduced in height but increased in width, and thus the machine is suited to fit the mining method and ore body, and not vice versa.

When doing the Mining Layout for the 16 West Mechanised Mining project one of the most important factors that was taken into account in the design was the waste dilution. The fact that we do have PGM content up to 2m below the UG2 reef horizon has helped to lower the actual dilution for the project, since the additional waste being mined is not going to the plant at a zero value. This means that when we refer to dilution we cannot simple state the percentage of waste being mined in the project. We have to measure dilution in terms of planned g/t to the plant and actual g/t to the plant. Dilution refers to the difference in grade between the planned cut for an excavation and the actual cut for the excavation. The grade refers to the 4E PGM value obtained from histograms, which is calculated from all the latest available Sampling values for the specific area, in g/t. The dilution is calculated with the following formulae and expressed as a percentage of the planned grade.

% Dilution = [(Actual Grade – Planned Grade) / Planned Grade] * 100

The mining cuts used to calculate the planned and actual grades for each end is determined in two ways:

- Measurements taken on the sidewall when doing sampling.
- Measurements from digital photos taken of the face as well as the sidewall.

The average distance between measurements from the combined methods of obtaining Stop Width control information is 10m.

The first method is a simple measurement of the Hanging Wall Waste, Channel Width and Footwall Waste mined and comparing this to the planned dimension of the ends in these specific positions. Also taken into account when measuring dilution is the amount of reef being left in the footwall or hanging wall as well as off reef mining. Dilution for each section is calculated for each of these sections after evaluating the measurements with the Histograms compiled for the working places. The second method calculations are exactly the same. The only difference is that the measurements are done on the computer screen on the digital photo rather than underground. This is achieved by putting a clino rule or photogrammetry stave against the face or sidewall to use in determining the scale of the photo. Once the scale of the photo is fixed you simply take the measurements on the photo by moving your cursor with the mouse to the points where you want to measure and noting the positions using the pixels in Microsoft Photo Editor or other similar software.

This second method gives us a lot more information than the first method. We can see what is happening in cases where there is off reef mining, reef left in hanging or foot, over breaking in hanging or foot, as well as bad hanging wall conditions without going underground to the specific working place.

As mining occurs on a true dip of 18° we need to cut our footwall back to 9° in our strike drives and declines. The effect is that any over breaking in the width of mining ends leads to additional waste dilution. The photos of the face allow us to measure the width of the ends as well as the actual dip of the footwall in an effort to control dilution in this section.

The 16West Mechanised Mining project was the pilot site for this digital photogrammetry project and we are looking at rolling this out to the conventional sections of the mine to improve the quality of our stop width control. There are however a few challenges ahead before this can happen. We have to automate the process of taking measurements on the photo and transfer this to our current stop width control reporting system. This is all being done manually at this stage and is time consuming, open to calculation errors if not checked thoroughly and needs to be done by a more senior employee.

The surveyor in this section is currently doing the photogrammetry or Stop width control for this section. The stop width control measurements is done daily when the surveyor installs pegs or samples in a workplace and surrounding ends. It is the intention to make this process simple enough for the MDP's, who do our Stop Width control in the conventional sections, to complete this process. The stop width reports are distributed daily to mining personal and best-cut comparison reports on a monthly basis.

Any photos of dangerous or substandard conditions are distributed on a daily basis as well.

Different methods of reef sorting include:

- Scalping, using screens.
- Resue mining.
- Waste sorting, using technology such as Micro-sorting.
- Waste sorting by hand.

Figure 1. Dilution comparison TM3 mechanisation and conventional mining.

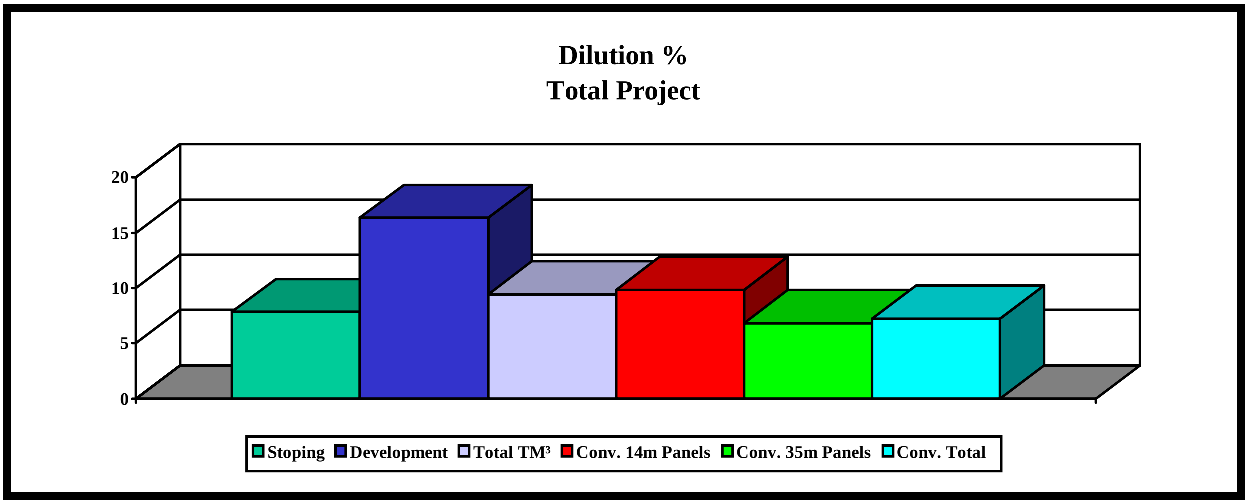


Figure 2. Comparison of different ends and also total dilution for stoping section.

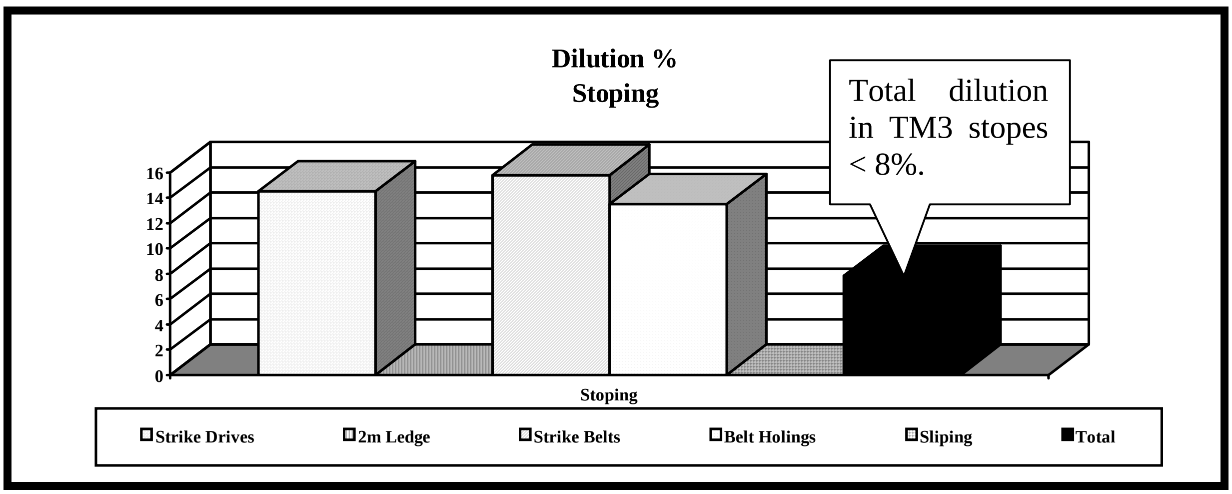
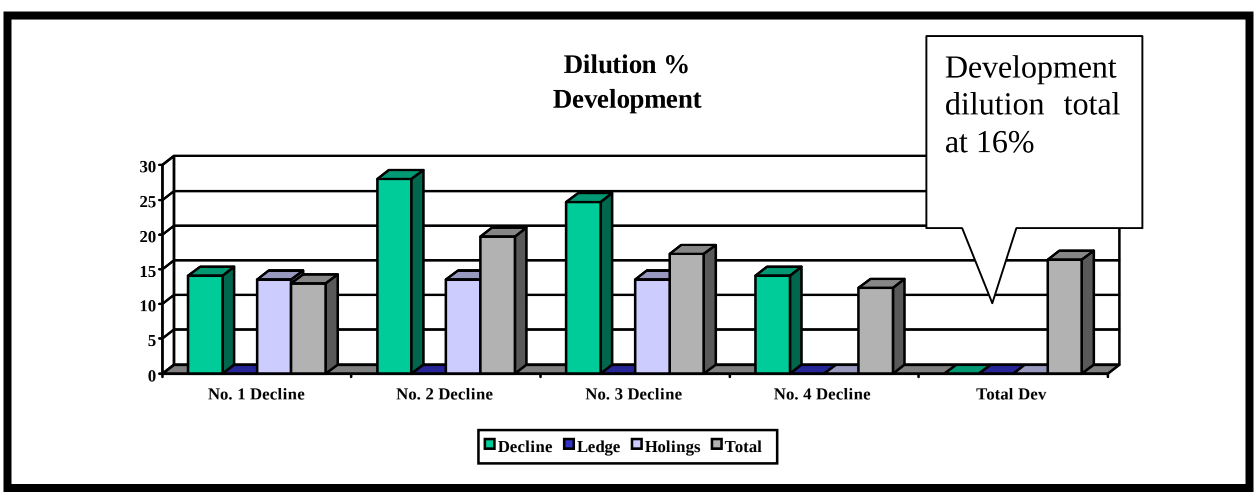


Figure 3 Comparison of the declines and their associated dilution.



Dilution control and management

It is of utmost importance to ensure that good controls are put in place, to manage and control dilution. The saying of “time is money” comes to mind, when one considers how long normal grade control reports take to filter through the in baskets of management, and usually with little or no effect on what is actually happening underground. Photogrammetry is currently in use on the majority of Anglo Platinum, Amandelbult decided to take this one step further by adding digital photo images, to grade control. The Photographer will go underground take photos, have them edited by the surveyor/geologist and then e-mail them to the respective parties. This will and should result in remedial action within the following shift, grade control being of crucial importance in trackless mining, this will result in the minimizing of lost revenue. Below is an example of a digital photograph taken, edited by grade control and e-mailed out on the same day.

Plate 23—Digital photo taken in the decline, indicating excessive footwall waste being mined.

PERSONNEL

The skills required to operate these machines, in these extreme conditions are not readily available, extensive recruitment testing is required, as well as extensive training and on the job coaching is continually done. When the operators were put through the battery of tests, it is found that very few possessed the co-ordination, mental aptitude, skill and competence to operate machines under these conditions. It thus requires a special skill, to operate these machines, obviously due to the scarceness of these skills; the remuneration of these operators will have to keep in line to retain the required skills.

Developing a modernised, and a human friendly mining method. As we come to grips with the reality of our future labour force, it becomes clear that many will not be able to handle the physical workload of the past. With the advent of technology coming into many sectors of the market, more demand will be placed on management, to evolve their method of work, from being physically intensive, to being more skill oriented and user friendly. Thus as Managers we will be called to design and develop mining methods which have a low physical workload and that enable all persons within the South African labour market to participate. Computers and more particularly the microchip have revolutionised the way in which we do things, people are not drawn to extensive physical work when there are far more technologically advanced jobs in the market. People want and require seeing advances in everything we do, and mining is not exempt of this expectation. Should we as the mining industry wish to draw some of the top workers in the labour market, we will have to be seen to be having some specific labour market differentiation, which draws the future potential employees.

Recruitment and selection of equipment operators

The impact of mechanisation cuts across all human resource issues and a dedicated resource should identify, evaluate and co-ordinate these requirements.

To efficiently select potential operators, the following needs to be taken into consideration:

- Measure the competencies required of a safe and efficient operator.
- Health and safety requirements also determine that the right person be appointed to the job.
- The Vienna Dover system is strongly recommended to be utilized as part of the assessment tools. Although not yet validated as part of the tools used in Anglo Platinum, it is in the process of being validated.
- NUM is satisfied that Vienna Dover be used as an assessment tool, and it complies with the crucial areas for validation e.g. culture fairness, credibility and reliability. Operations like Transnet, Grinaker and MMC are effectively using it.
- To purchase the necessary equipment, (including the training on the use of it), is currently in the region of R 95 000.00 (2001), as the equipment is imported from Austria.

- The ideal situation is to have a qualified Psychometrist perform actual assessments, as the interpretation and report writing is of a high complexity. It is also directly related to job specifications, and needs to be administered as such.

Assessments required

Existing employees and novices;

- In both cases the following assessments need to be conducted to establish suitability to be trained as operators
- English proficiency (at least a competency on grade 9 level)
- Medical assessment
- All elements described in the Vienna Dover testing system as being applicable per job category (this will include trainability)
- The Vienna/Dover test Measures the following:
    1. Hand, eye, feet and hearing co-ordination.
    2. Concentration ability.
    3. Stress tolerance level.
    4. Ability to judge the speed of a moving object.
    5. Depth perception.
    6. Attention to detail under stress.

The theory behind the development of the test was that a well-coordinated person would be a more competent driver/operator of moving machinery with multiple controls or motor vehicles.

This theory was substantiated by various organisations, such as Target Gold Mine and ISCOR who after the introduction of the test as a selection tool experienced a significant reduction in machine breakdowns and accidents.

In some European countries such as Germany and Switzerland there is a drive on to introduce the test as part of the competency test for the issue of public transport and heavy vehicle drivers licenses.

The Vienna/Dover test was used extensively for many years by the international mining industry and the ability to judge speed and depth was accommodated in the test at their request. This was done to reduce the risk of accidents and damage to machinery in confined spaces that is found in a mining environment.

Basically one can argue that the introduction of the Vienna /Dover to the South African mining industry is not only in compliance with international best practice, it is also a good business decision. With the move towards mechanised mining where "down time" of machines can break the business.

The motto to keep in mind is "The performance of your machines can only be as good as the quality of your operators."

MACHINERY SUPPLIERS

Low profile machinery

The main suppliers of low profile underground mining equipment have aggressively embarked upon a race to ensure that they gain their portion of the market share. The majority of suppliers have available, a full fleet of low profile machines. The introduction and development of these machines has allowed the South African market, the means to mine its narrow ore bodies. The main players as we experienced them in the hard rock S.A. market are currently:

- Sandvik-Tamrock
- Atlas Copco
- Boart longyear

Suppliers, which are currently busy gaining market exposure and developing their products, are:

- DBT and incorporated within them Long Airdox
- RHAM
- Fermel

Unique machines, which have been developed for and at Amandelbult, include a low profile grader, a low profile back actor, and a diesel and lube cassette, as well as a low profile roof bolter. The intention was that one supplier must be able to supply the full fleet of machines, thus reducing the stockholding of spare parts and the maintenance staff required to maintain the machines. The grader, back actor, roof bolter and utility vehicles all have the same power plants, thus engine spares are all the same. The specialist attachments have been developed by specific manufacturers and then fitted on the machines.

The grader was developed by the suppliers in conjunction with the relevant mine staff, it is the first South African low profile grader, at a height of 1.65m. It was built and manufactured in SA; the grader specialist was a company at the coast, namely DEZZI. The power plant was the rear end of the Aardmajor, the grader ensures that the roadways, are kept level and in good condition. Thus improving roadway conditions, which in turn improves driving, as well as reduces required maintenance on linkages, etc. The other benefits include tyre life and tramming speed, as well as driver comfort.

The roof bolter is unique as it is South Africa’s first low profile roof bolter, it can drill up to 8 roof bolts from one set up position, thus minimising set up time, which usually consumes the most of your operating time. The drifter fitted, is one of the smallest in the world and it can drill both rotary and percussive, to enable the drilling of roof bolts as well as there installation.

The back actor was developed as a machine, which could be used to clean the footwall of development ends, as well as remove broken rock of the ledges.

The lube cassettes were developed to enable the machines to be refueled underground at the stope face, as well as lubricated. This enabled us to keep the machines at the working face, and refuel them during the shift, thus no time is lost traveling to refueling points. The other advantage as that with the 1000 litre tank we are able to keep a day or two worth of diesel supply underground, thus we have also got away from all the issues surrounding the piping of diesel underground.

Issues to consider when purchasing a fleet of equipment:

- The availability of competition in the market and alternate suppliers.
- Capital outlay
- Running cost
- Exposure to the exchange rate
- Safety systems included, or as the purchaser adds his safety specifications does the price of the machine double.
- The legal systems, which are required to operate and maintain the machine.
- The openness of the supplier towards a full maintenance contract.
- Life expectancy of major components, and replacement schedule from the supplier.
- The consumption of diesel, spares and tyres, given certain operating conditions.
- The set up and moving time involved with drill rigs and roof bolters, the reach of the boom/s from one set up position.
- The production capability of the fleet, the LHD's and drill rigs, taking in cognizance the operating conditions
- The expected availability of the fleet and the specific machines.
- Does the machine fit the mining area, or do you have design the mine around the machine, is it minor or major changes required.
- Does the supplier supply the whole fleet, or do you have to have many different makes/ types of machines to make up the fleet.
- The user friendliness of the machine in a third world environment, with possibly illiterate operators.
- The amount of technology on the machine, which takes a hammering underground in a wet and dusty environment.
- The amount of technology which requires constant upgrades in IT and IS
- The complexity of operation and maintenance

- The amount of flexibility allowed on the machines to enable changes.
- The supplier's commitment to the product.
- The amount of Research and development, done on an ongoing basis by the supplier.
- The after sales service, when break downs occur how long does it take, for the supplier to repair or source parts, as this is where the most revenue is lost, when no production is possible.
- Ergonomics' of the operator.
- Ease of maintenance in the stope or development end.
- The reliance on intricate systems, to ensure optimum performance.
- The acceptance of the machine by the operators.
- The axle maintenance and guarantee's thereon
- Maintenance repair contract, and the availability of staff to operate and service the machines.
- Proven track record, where are the machines currently operating with success.
- Credibility of supplier in the appropriate market.
- The availability of spares.
- Stock holding, what stock are you required to hold, is it consignment stock?
- Standardising on what type of machine, to limit stock holding and training of staff.

CONVEYORS

Proving the viability of implementing trackless mining with conveyors was put to trial in three phases, which will be discussed below.

Phase 1

Phase one consisted of developing the reef drive, vent raises, and 4 declines by means of LHD's and dump trucks. A waste ore pass and hydraulic rock breaker were utilized to process the waste rock generated. Decline 2 has heights of 2.5 and 3.1 meters respectively, and a width of 4 meters, the reason for this being bigger is that the main belt runs in decline 2, as well as all the utilities, such as water, air and electricity.

Phase 2

Phase two consisted of installing the main, strike and feeder belts, to reduce tramming distances of machines. The belts are laid out in a herringbone pattern, offset at 30°. The belts are extended periodically to attempt to maintain a tramming distance of no more than 75 meters. The first main belt will eventually be 600 meters in length, with 3 strike belts of 60m lengths, each with 3x20-meter feeder belts. There will also be 3 extra 20-meter feeder belts onto the main belt. All the belts have rip detection; rollback safeties, tracking monitor, emergency pull switches, bin full cut out, and slip detection. The main belt has a double brelko scraper system, while the smaller belts only have a single brelko scraper.

The belts are suspended from the hanging wall, which cuts down on structural steel, and makes installation and extensions much easier and faster. The belt system is controlled via a dedicate PLC with mimic display. For detailed specifications of the conveyor mechanicals, drives, structures, take ups and belting, table below.

Table 1- Belt design criteria

Belt	**Design Tonnage**	**Belt Speed**	**Width**	**Class / Ply**
Main	400 T/HR	2.1 M/S	900 mm	1000/4
Strike	150 T/HR	2.1 M/S	900 mm	315/3
Feeders	150 T/HR	1.1 M/S	900 mm	315/3
	Covers / Grade	**Motor Power**	**Gearbox Ratio**	**Take-up**
Main	5 /1.6 mm	2 X 110 kw	25;1	12 m travel
Strike	5 /1.6 mm	45 kw	22;1	12 m travel
Feeders	5 /1.6 mm	7.5 kw	31;1	300 mm travel

Phase 3

Phase three will consist of installing a conveyor from the discharge end of the main conveyor running all the way up to a new surface silo. This phase is currently in the CBE phase, awaiting submission to the board for approval.

Advantages and disadvantages

The advantages of having a conveyor system in conjunction with a trackless section are as follows:

- You only handle the ore once, compared to several times in a conventional mining method.
- Reduced tramming distances.
- Reduced machine maintenance costs.
- Reduced dependence on Loco, hoppers and winder.
- Reduced downtime due to box hang-ups.
- Eliminate risk of box mud-rushes.
- Low belt maintenance costs.
- Eliminate dangers and risks of incline shafts and associated derailments, etc.
- Reduced cost per ton reef produced.
- Steady reef flow to surface silos.
- Stockpile facility.
- Low skill level operational + maintenance crew required.

The disadvantages as follows:

- High initial cost.
- Fire hazard.
- Interlocking management of belts.
- Dependence on single system, no flexibility.
- Inherent dangers associated with conveyor belts.
- Limited size of broken rock, large rocks must be handled at the screen or else they land up damaging the belt.
- Supervision (tipping point attendants) required.
- Geographically large area for overseeing.
- Extensive sliping (waste) required for installation.
- Skilled labour required for installation.

Considerations when ordering a belt.

- Consult your Engineer.
- Tons / hour required.
- Vertical lift.
- Horizontal distance.
- Suspended or free- standing structure.
- Electrical capacity available.
- Material density.
- Average material lump size.
- Wet or dry material.
- Impact area design.
- Transfer chute design: - especially where changing direction of flow.
- Max permissible belt speed **(ventilation)**.
- Take up design.
- Space available.
- Stockpile capacity.
- Other belts feeding onto main: - Inter locking chute clearance wind loading **(If on surface)**.
- Clearances over roads, power lines, etc.

Conveyor safety devices required

- Roll back and rip stop protection.
- Alignment protection.
- Guarding.
- Inter Locking.
- Emergency pull switches.
- Start up siren.
- Wrong direction protection.
- Emergency stops.
- Overload protection.
- Belt slip protection.
- Fire fighting equipment and flame retardant belting.

COMMUNICATIONS

At Amandelbult it was decided to opt for the radio and leaky feeder system rather than telephones. The advantages & disadvantages are discussed below.

Advantages

- Can be used anywhere where there is a fixed point in the vicinity.
- Can phone out with radio to any telephone.
- More robust than telephones.
- Can use while mobile.
- Can speak directly to operator, etc.
- Relatively low maintenance.
- Versatile.
- More reliable than telephone system.
- Easy to extend.
- Is continually in use, so faults are picked up & rectified quickly.
- Is not affected by voltage surges & drops.

Disadvantages

- Relatively expensive initial cost.
- Needs specialist installation & maintenance.
- If main amplifier out of order, whole system down.
- Prone to lightning damage.
- Radios get lost and or damaged.

THROWBLASTING

The incorporation of long hole drilling, into the areas was based on the idea that one could successfully blast out the stope without actually entering them. The limitations of the equipment available and the size of the ends enabled us to consider throw blasting 4m stoping rounds into the drives. The room and pillar idea at semi- steep dips is more a long hole stoping technique, than it is room and pillar, as all stoping is done from the development ends.

Figure 4—Plan of the throw blasting area within the stopes.

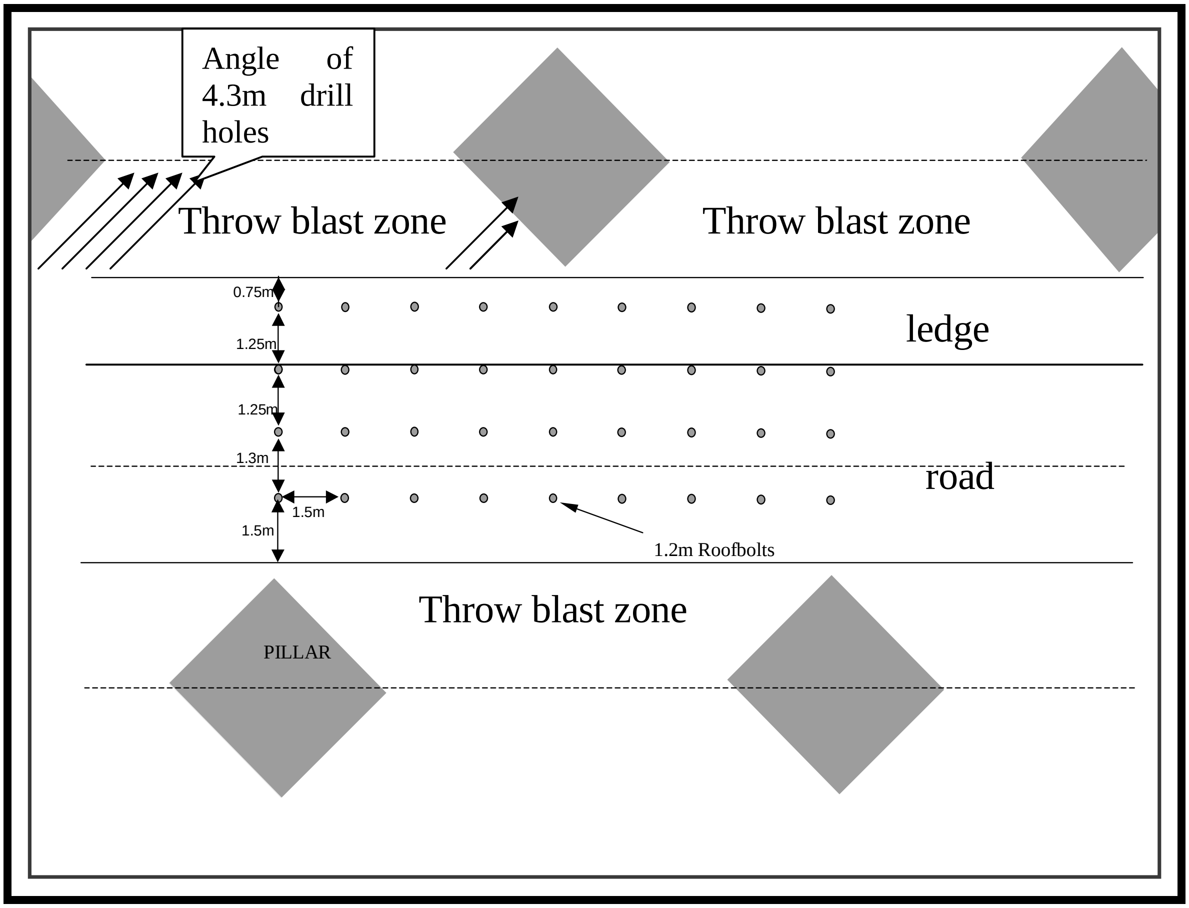


Plate 10—Photo of a stoping area that is ready to be drilled once the 2m ledge has been cleaned and marked off.

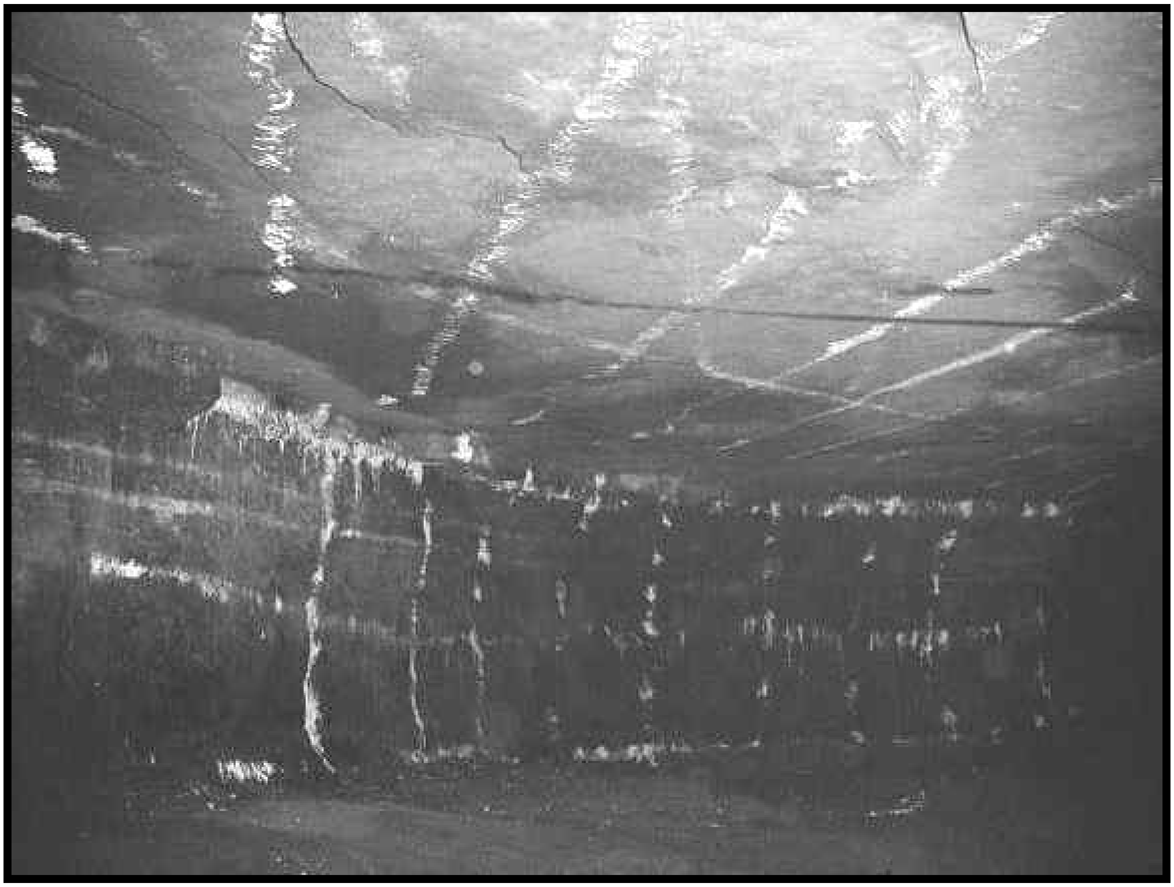
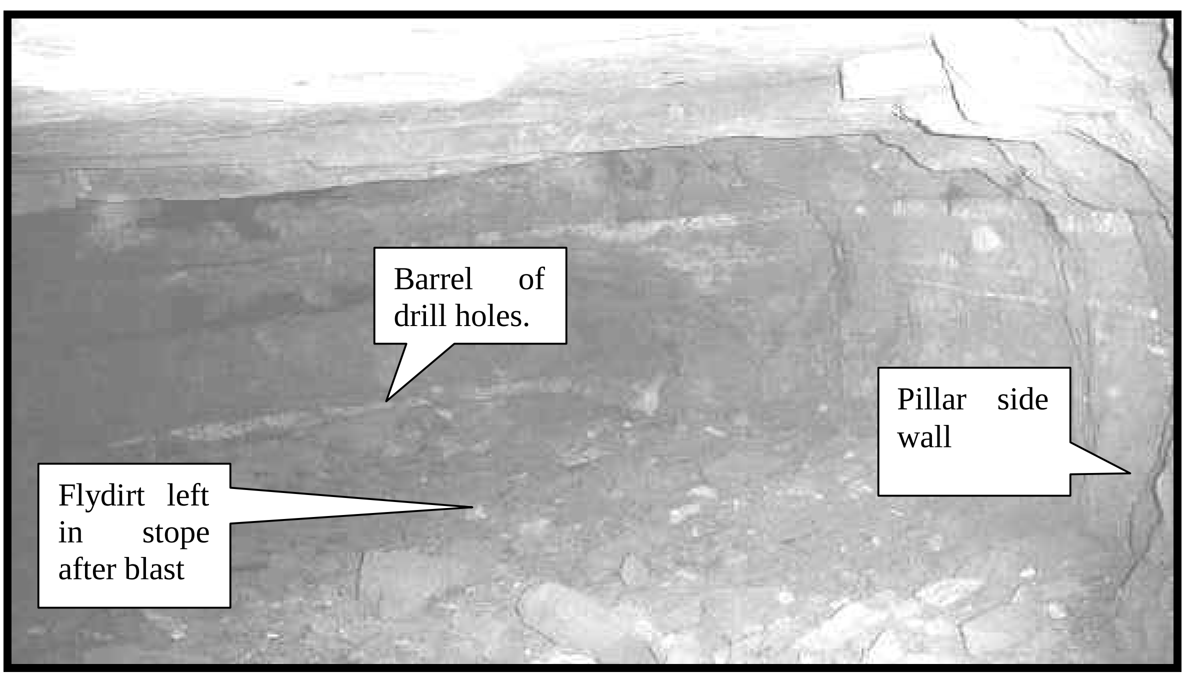
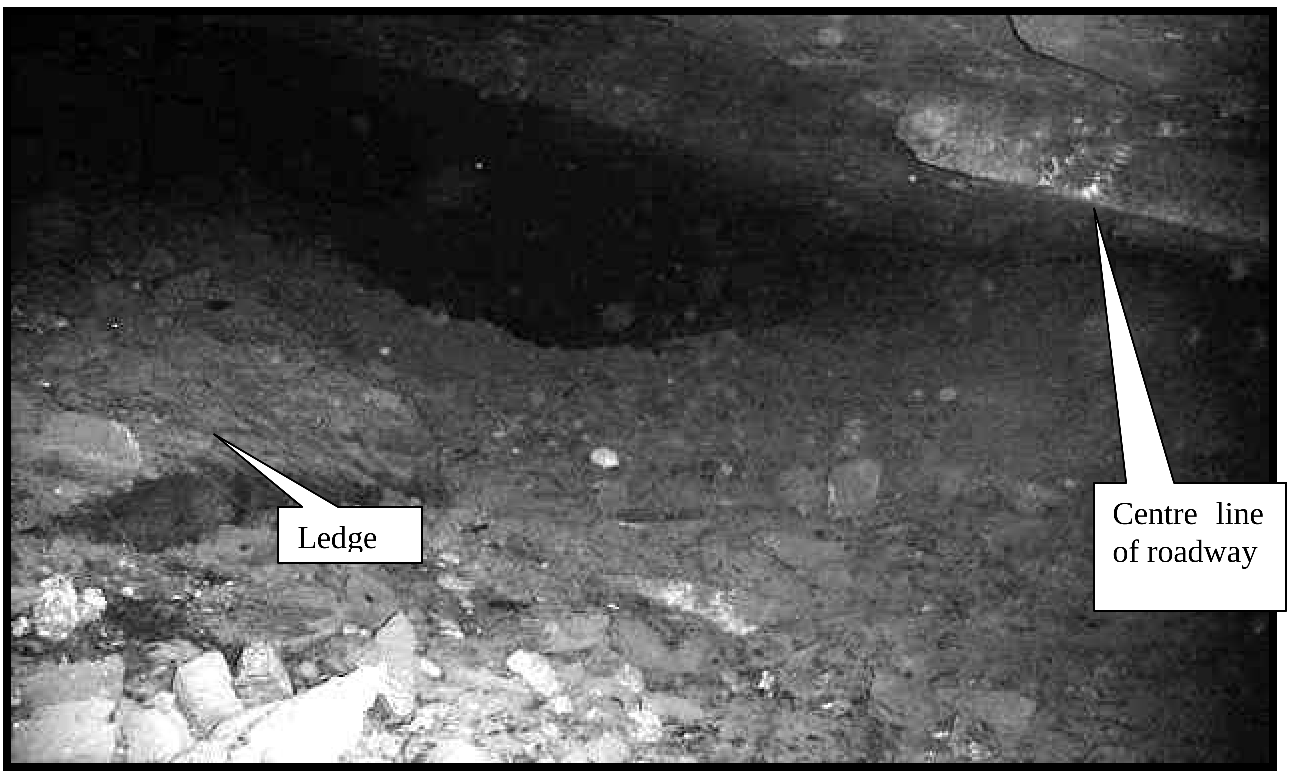


Plate 11—Stope after the blast has been performed



Once again the microchip has revolutionized another ancient old tradition, in the past the miner use to prime cut his fuses, make up his primers, charge up his holes with gelignite cartridges, take a flaming cheesa stick and run done the face, lighting all the protruding fuses, hoping that he had lit all of them. Then came the advent of ignitor cord, the safety fuse and anfo/ex. A next step was the introduction of cortex, electric blasting, emulsion and shock tubes. Today the miner has at his assistance, an electronic delay detonator, this enables the miner to ensure that each hole goes off sequentially within milliseconds off each other, and using the forces he can basically get the rock to do as he wishes. It is no longer luck, but pure science and each round can be designed and timed to do precisely as the miner wishes. Not only do the holes go off as he requires, but the detonators actually communicate back, and give a clear indication of the success of the blast. With all this technology at hand, it was decided to use the explosive forces to do the majority of the required cleaning, thus minimizing the amount of secondary cleaning off the ledges. The trials are still on going and at this stage the potential is definitely there, it is simply a matter of fine-tuning now.

Plate 12—Muck pile heaved into roadway by blast.



SMART BOLTING

Smart bolting, as designed an laid out below by Peter Altouyan of Rock Mechanics Technology, was considered the best option, as both projects are shallow, and an extremely reliable stiff support system would be required. The mining area has only pillars and roof bolts for support, thus it was an imperative for management to ensure that the best possible support system was installed. The support would also have to stand up to significant punishment taking into account the length of rounds being blasted as well as the throw blasting, in close proximity of the bolts. The specific areas on the Ug2 have an incredibly hard and brittle layer of Harzburgite, just above the top Cr contact, the Pyroxinite rock layer above the Harzburgite is soft in comparison, see Table 1 below. This layer of proximate acts as a sponge and is elastic, it thus bends and moves, but the Harzbergite is unable to, as it is like glass, thus it shears of under the high horizontal stress. The roof bolts must therefore be stiff, to keep these layers in place. Therefore a stiff 1,2m roof bolt has been chosen. A section of the roof bolting is shown in Figure 6, as well as a plan of the roof bolting pattern is shown in Figure 4.

Figure 13- Indicating the rock layers experienced and the difficulty in controlling the Harzburgite using standard grouted roof bolts.

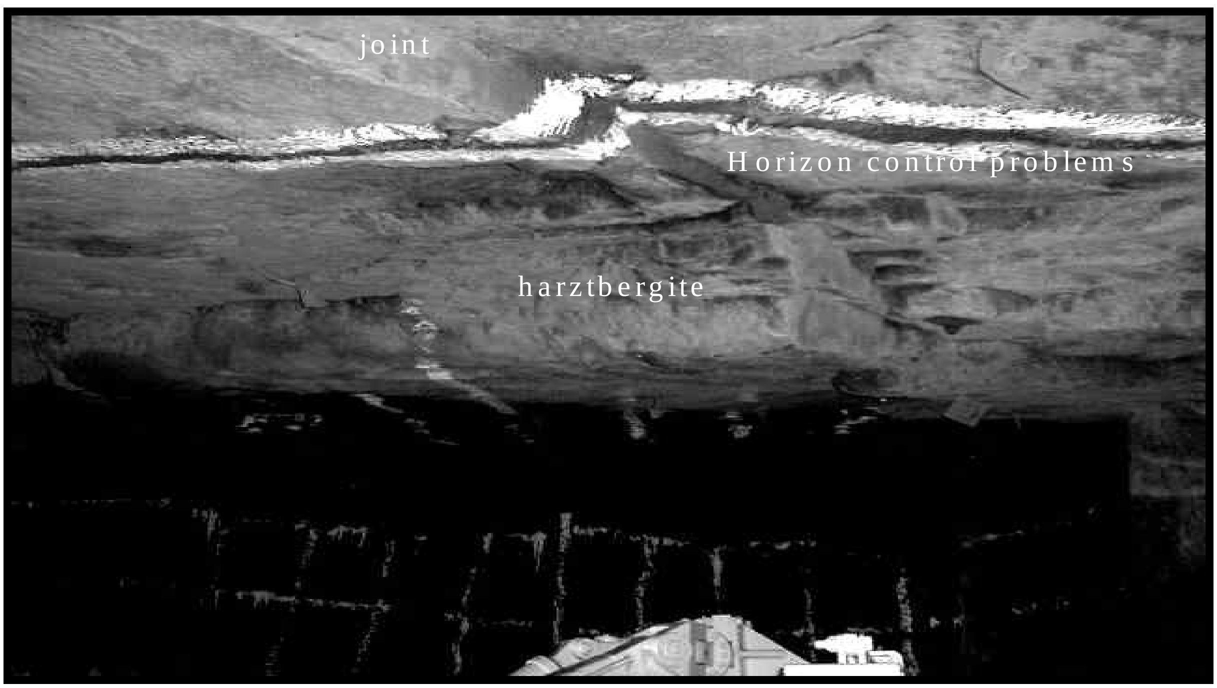


Figure-14 The effect of high horizontal stresses on the Harzburgite, as well as photo indicating the shearing of the layer.

Figure-14 The effect of high horizontal stresses on the Harzburgite

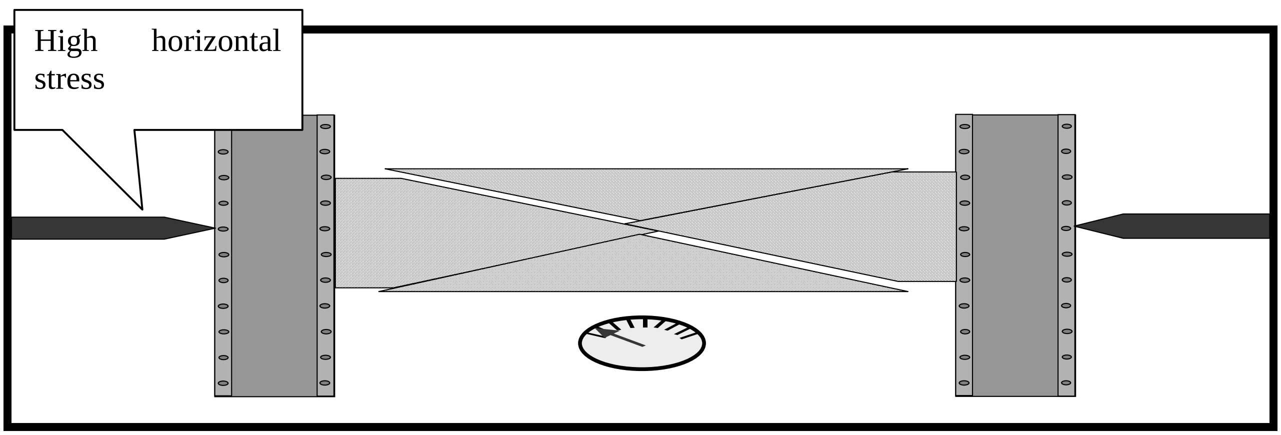


Figure 15—Section of stope drive, showing the installation of roof bolts

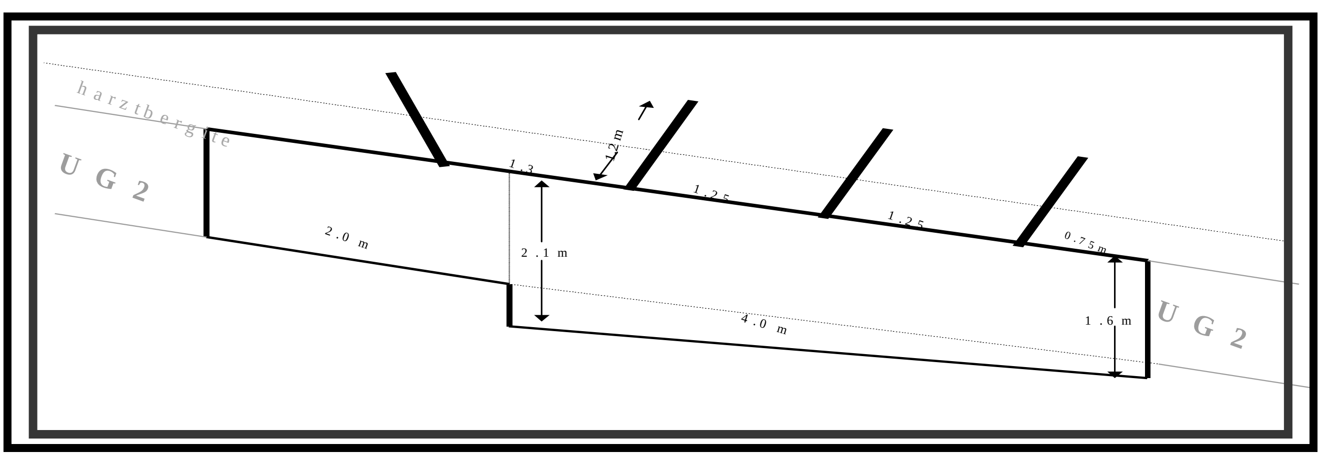


Table 2 representing the hanging wall rock properties, indicates what has been described above with the brittle Harzburgite and compressive Pyroxenes.

Hanging wall rock properties

	Strength UCS MPa	Modulus E GPa	Abrasivity CERCHAR INDEX
hartzbergite	75	204	3.6
pyroxenite	160	83	3.8

The principles of smart bolting are discussed below:

- Understand failure mechanism
- Using an effective support system
- Design by measurement
- Monitor the performance

When designing a support system we usually look at factors like what is the average size of the Fall of Ground for the area/ mine, we then gather a statistical database on the above mentioned and then design our support system to cater for at least 95% of this block height. We also take into cognisance issues such as support density /coverage (m2 / unit), support resistance and depth below surface. On Amandelbult we also take the Voisours arch into cognisance, particularly in shallow areas, where high horizontal stresses are experienced. Other factors would also include issues such productivity, ease of installation (user-friendly), availability and the competency of the supplier, to do research and ensure a sustained supply. The smart bolting takes into cognisance all the above, but is not so rigid as other support systems, that one size fits all, it does not support a blanket system for the whole area/ mine. Each area will have different requirements, being dependent on the specific to that area, factors such as stresses, geological anomalies and mining patterns. It thus focuses on local support and not regional support. The below mentioned Figure… represent what a common support system would allow for, while figure…indicates what Smartbolting allows for in the support system.

Figure 7- indicating what a normal blanket support system allows for.

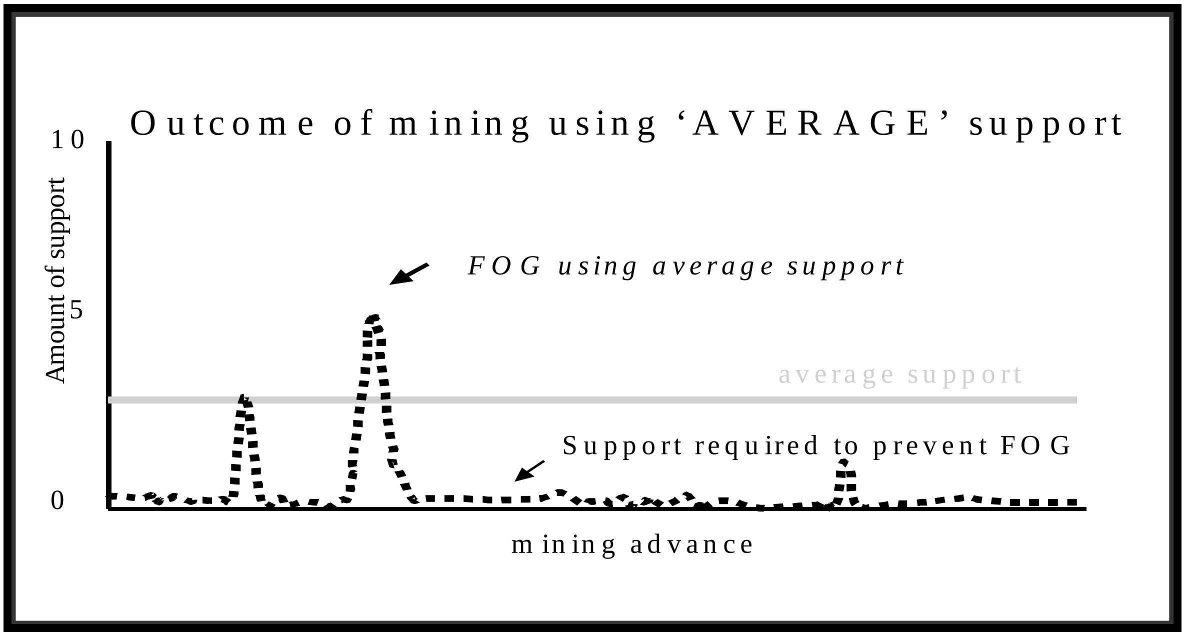
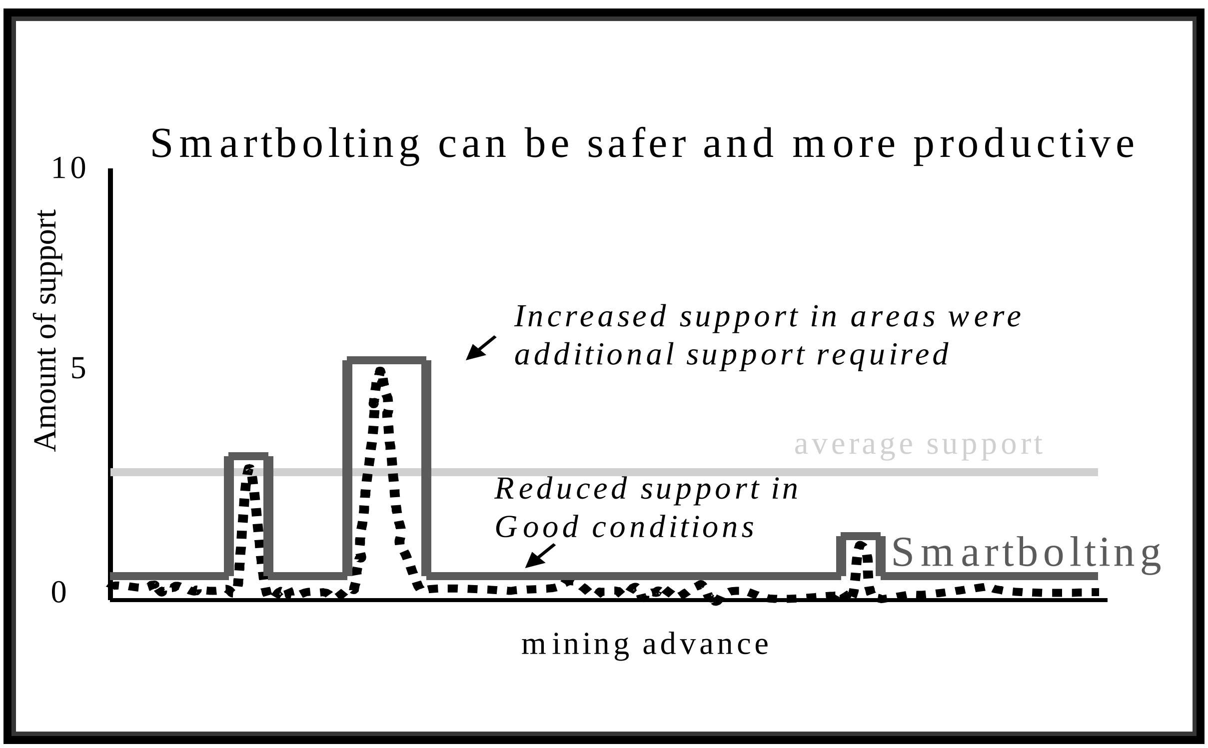


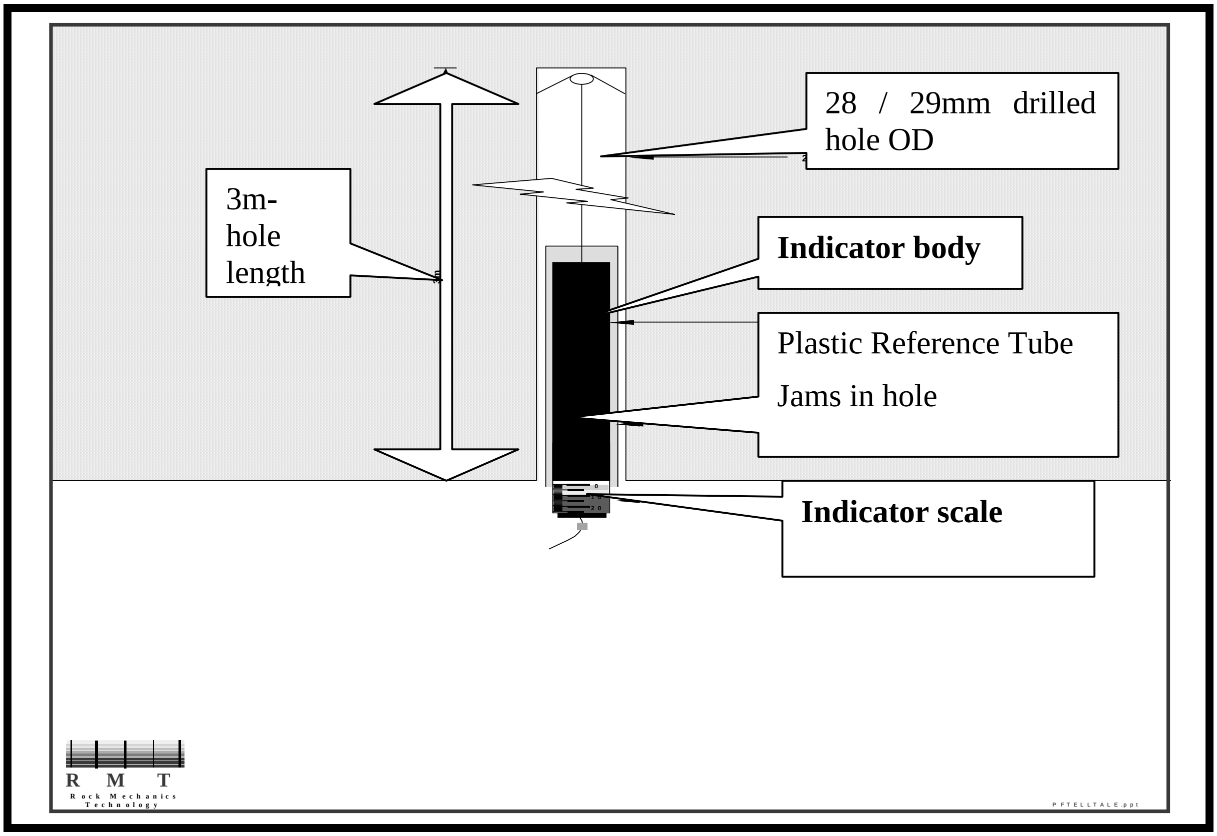
Figure 8-indicates how support should be installed to eliminate over supporting, and ensure that bad areas requiring additional are adequately supported.



Smart bolting thus allows the manager to systematically support the workings of the mine, using an effective design, by measuring constantly what the hanging wall is doing.

It also reduces wastage, and over supporting, resulting in time saving as well as better productivity, as less resources are applied to support. Though when an area requires additional support, which has been indicated by the extensometers or tell tales, then instead of it costing more, it requires that the correct support is installed. The effect of this increased support can also be measured and thus we are ensured that we know that our actions have worked for us. Should the support have not stopped the area form deteriorating then even greater effort can be applied, and eventually if all else fails, the tell tales will inform management and workers to stay out of the area.

Figure 9—Telltale parts compliments of R.M.T.



Spin to Stall

Spin to stall resin rock bolt System

All the materials and bolter performance must be correctly specified otherwise it won't work! Should the hole be drilled to short, the diameter of the hole to wide, or the resin be faulty, then the system will fail, and the installation will have to occur again.

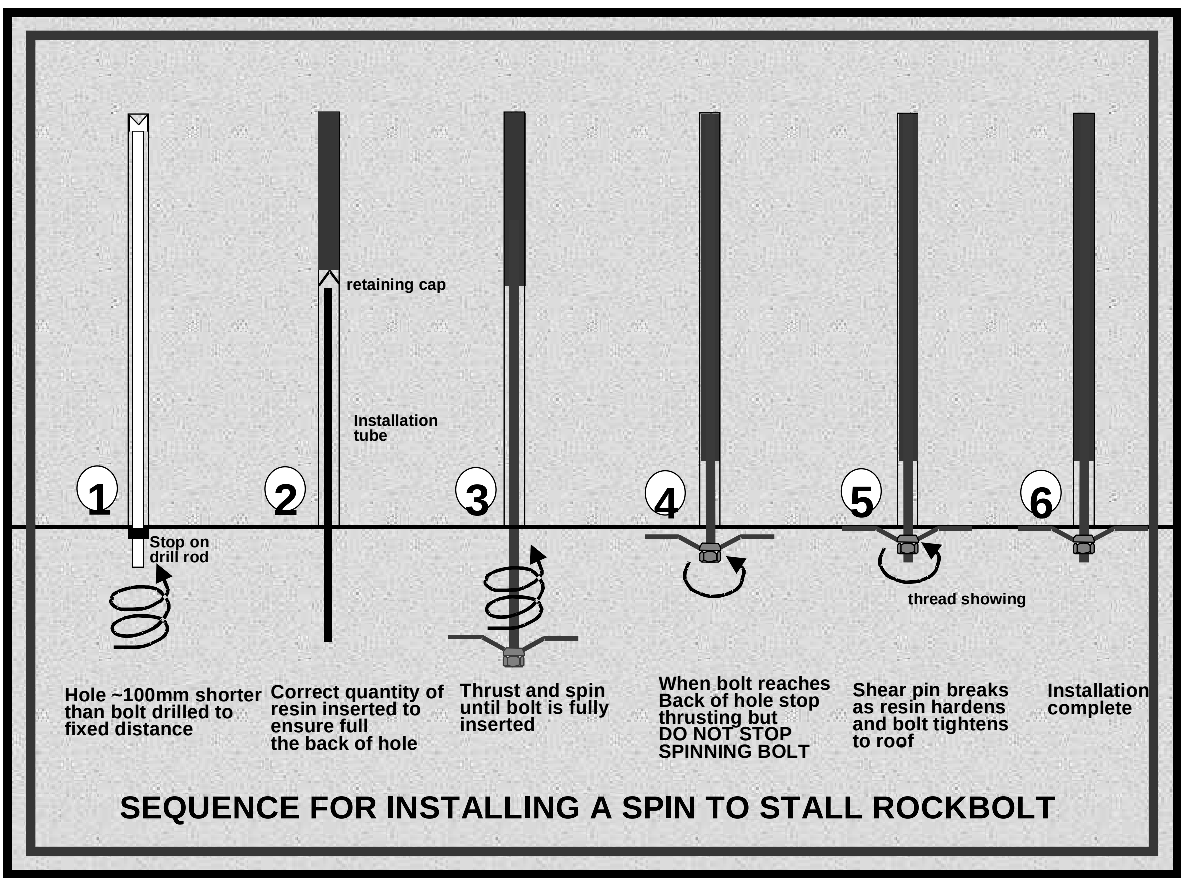
If it doesn't work there is something wrong with the bolter machine or the materials! This is a good indicator for the operators, workers and managers that their support is effective, and also results in immediate corrective action been taken. Should the bolter drifter not spin the at the correct speed then it will be indicated immediately by the bolt installation.

It is a system if you change one element it will probably fail! The system is fairly fail safe, thus as the manager you are ensured that your roof bolts are correctly installed.

The requirements of the roof bolt to function optimally in a smart bolting system:

- Prevent hanging wall movement.
- Must be a stiff system.
- Enough coverage to prevent block fall out.
- Maintain hanging wall stability on development and after sidewall blasting.
- Robust enough to handle blasting.
- Simple to install correctly difficult to install incorrectly.
- Able to assess quality control.
- Rapid installation using mechanised and hand held bolter.

Figure 10—Sequence of installation of spin to stall resin bolts



Requires training for operators, supervisors and rock engineers. Skilled staff is required to operate and ensure the success of smart bolting; everybody has to understand the system and what the effects are should something go wrong. The understanding of the indicators in terms of the extensometers and tell tales is also vital, as this data needs to be analysed and acted upon, to ensure the safety of all persons.

Monitoring of movement, the on site personnel are trained to read understand the tell tales, they now have a warning, which tells them what the hanging wall is doing, should they still proceed to work in a certain area, or should they abandon the area. Thus the system is pro- active in warning people when and what to do. The extensometers though require much more detailed analysis by the rock engineers, who have to interpret data, and react accordingly to ensure local and regional stability. Thus the manager should be able to prove that he has an adequate support system in place, and that he has applied due diligence in ensuring the safety of his people.

Monitoring is the final check on the system, as mentioned above it is probably the most important function in smart bolting. Should a low bond strength resin have been used the movement will occur, and this can be picked up by monitoring. A Stiff bolt and the correct resin will ensure that no movement takes place, and if movement does take place, then serious action may be taken.

If it doesn't move it can't fall. The stiffer the support system the better with high horizontal stress, as well taking into consideration the shallow depth of mining as well as the beam being created in the hanging wall.

Figure 11—The workings of a tell tale, easily understandable even for an illiterate worker.

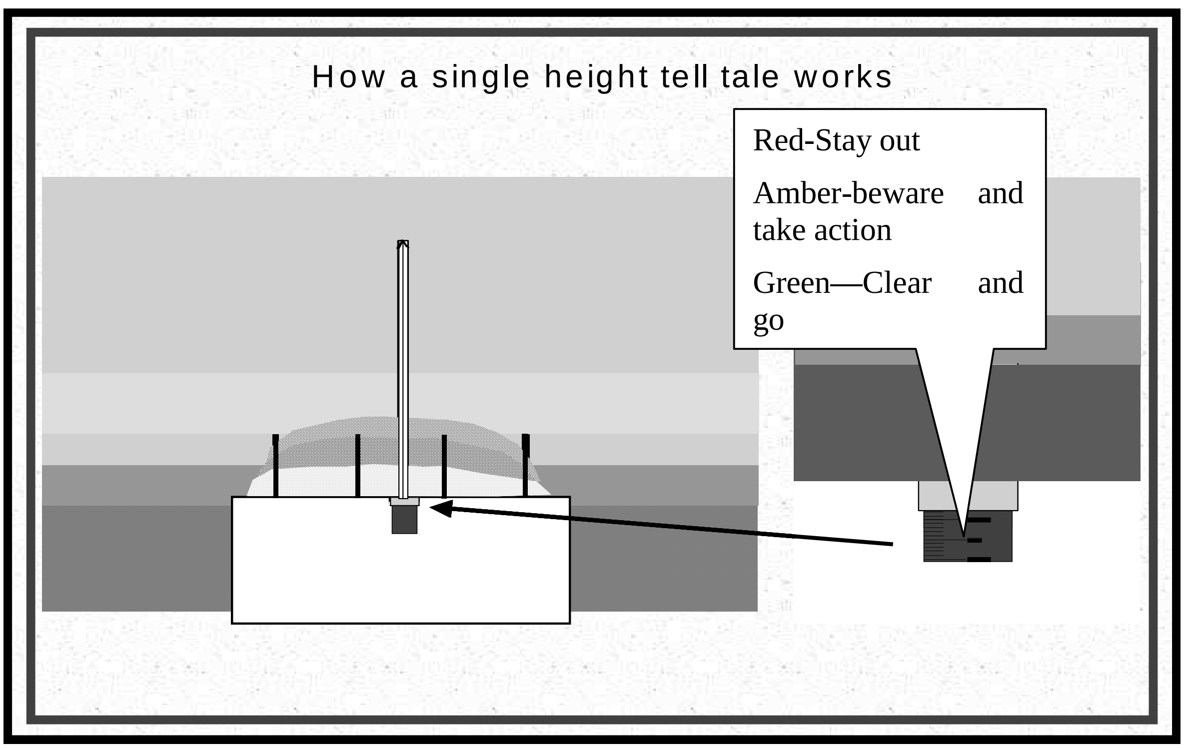


Table 3 below indicates the action required when tell tales begin indicating movement.

TELL TALE ACTIONS TABLE

INDICATION	MOVEMENT	RISK	ACTIONS
From single Tell tale	Small movement & Stable trend	Low	No action required, continue Routine monitoring
		Medium	Install additional reinforcement, length & type determined by investigations Coordinated by Roof Control Officer
	High movement & Unstable trend	High	Restrict access, consult Roof Control Officer
From multiple Tell tales	Small movement & Stable trend	Low	Maintain or potentially reduce current level of support. If reducing support confirm design using extensometers. All changes to support design made by senior management.
	High movement & Unstable trends	High	Current support inadequate. Increase level of support as indicated in table 2 or through assessment by Senior management / Roof Control Officer / Rock Engineer

R M T
Rock Mechanics Technology

<u>Extensometers</u> will allow the below mentioned to take place:

- In ‘areas of concern’ install alternative support.
- Monitor routinely and take action accordingly.
- Equipment shown to be very sensitive to small movements.
- Extensometers will TELL YOU HOW HIGH THE HANGING WALL IS MOVING and therefore the length of bolt required.
- More extensometers will be required in areas where movement is likely e.g. domes, in wider openings.
- Assess hanging wall prior to throw blasting.

Figure 12—The working of an extensometer

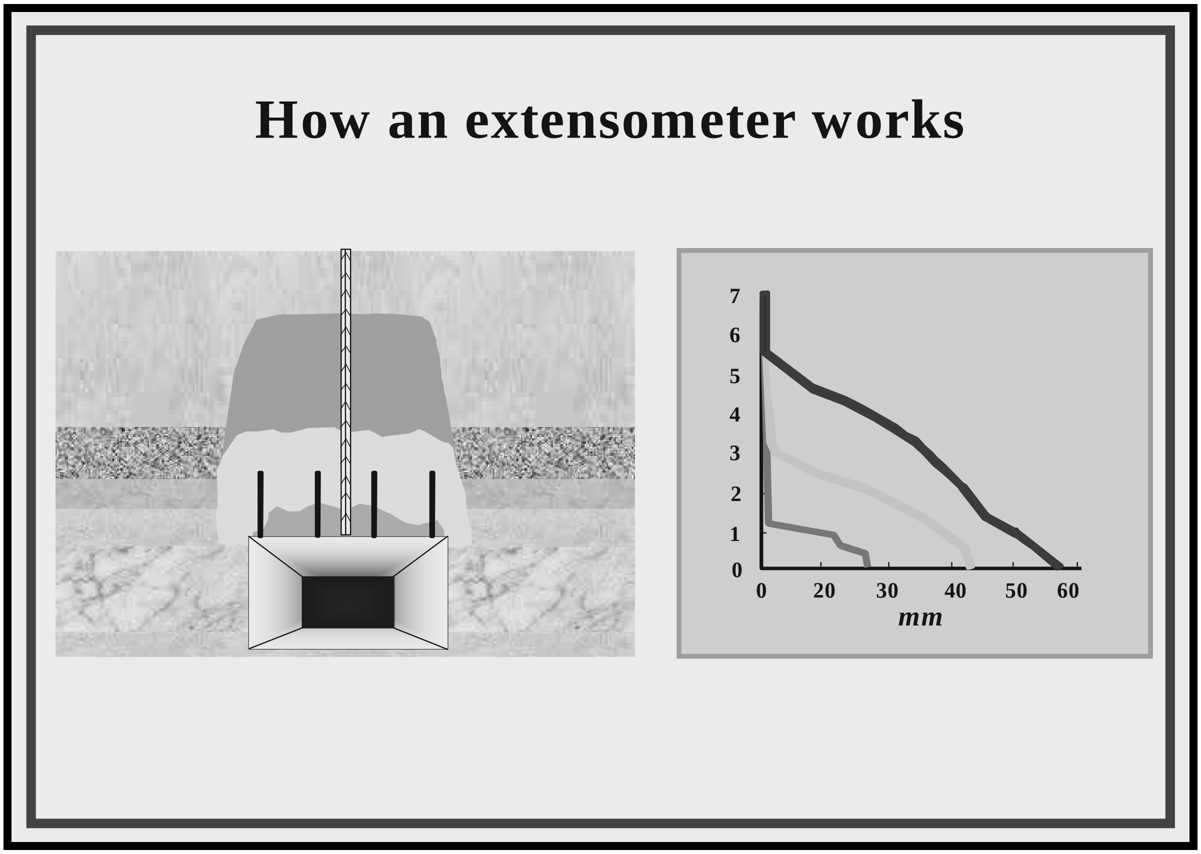


Table 3-Costing comparison of support cost vs. conventional stopes at 2001

Costing of the STS Resin Bolting System

ANGLO PLATINUM

- **<u>Cost of proposed support system</u>**

- Total tributary area per Bolt = 4.35 m^2
- Cost of High Profile S20 Step Bar = R 18.86
- Cost of 23mm x 600mm 30 Sec Resin = R 4.32
- Total Material Cost / Installation = R 23.18
- **Resin Bolting Cost = 23.18 / 4.35 = R 5.33 / Ca.**

- **<u>Cost of current support system</u>**

- Pre-stressed elongate R 46.56 / 6 = R 7.76 /Ca
- FCG Shell Anchored Bolt R 14.00 / 2.25 = R 6.22 / Ca
- **Conventional Support cost = R 13.98 / Ca**

ROCK ON FLOOR

Rock on floor blasting contract was to ensure that the maximum advantage could be achieved from new technology in the explosives industry; it was decided to outsource explosives and charging up. This enabled the supplier to take advantage of his expertise in his product and him ensuring the product remained viable. The opencast charging up method was used as a principle to work on, where should any blasting deficiencies occur, the supplier is held accountable as well. The contract is written in such a way that the explosive supplier is paid for each ton of rock that is measured as broken, the cost works on an exponential scale, where the initial tons blasted are very expensive, and the greater the tonnage, the less the cost per ton, but the greater the revenue. Thus the contract is written on a win- win basis.

Plate-15 Low profile drill rig, drilling the face, effective 4m advance is achieved, using E.D.D.'s and emulsion.

The supplier of explosives may reject a poorly drilled round and thus the operators and supervisors are forced to ensure that the quality of drilling is excellent. The explosive supplier is paid on a rate per ton mined, and thus they have an interest in ensuring maximum blasting efficiencies are achieved.

A 6-month trial was done to establish the benefits that could be achieved using pump-able, emulsion based explosives and an electronic initiation system.

Products used

Sasol Explosives' tender was based on the use of its proprietary DDS™ (Development Delivery System) pump-able blend explosive in conjunction with their EZ Tronic™ electronic initiation system. Consisting of a blend of EXPAN™ (un-fuelled, low density, Ammonium Nitrate pill), waterproof emulsion and sensitizing agent. The DDS™ product is stored as separate components and transported underground to the working faces, where it is mixed and pumped in to the blast holes ready for initiation. The electronic detonators are stored underground and used in conjunction with a 15g Stinger™ Pentolite booster as a primer in each hole. The detonators are individually labeled with a unique bar code, which is scanned in to a central blasting box for remote initiation at a pre-determined time.

Equipment & Logistics

The DDS™ suite of equipment consists of a pumping unit, surface emulsion silo, emulsion transfer bins and an emulsion transfer pump.

The DDS™ unit is mounted on to a cassette platform that is detachable from the utility vehicle used to move the unit from surface to underground and between faces. With a carrying capacity of approximately 1,100 kg of individual components, the DDS™ unit is used to charge up several faces before having to return to surface to re-fill with emulsion. Emulsion will be transferred underground in future, via 1-ton, stainless steel bins, which will be off loaded in the transfer bay ready for re-filling of the DDS™ unit. The utility vehicle will then only be required to return to surface for maintenance, re-fuelling and statutory inspections. The surface silo has a capacity of 20 tons and is not subject to any blast circle restrictions as the emulsion is classified as a non-explosive oxidiser. The sensitiser is delivered in 25-liter drums and is also stored as a non-explosive component.

The EXPAN™ is transported, stored and handled in the same manner as ANFO and is delivered in 22kg bags. The electronic detonators are stored in the normal manner with permanent underground electronic blast boxes installed for initiation of the rounds. Water for the DDS™ unit was taken from the underground reticulation system and no special requirements were needed in this regard.

Organisation

Sasol Explosives appointed a site supervisor to oversee the day-to-day management of the operations. Reporting to him are Sasol certificated miners who liaise with the responsible section miner as to which faces are being blasted and what the requirements are for the DDS™ unit. Each of the Sasol miners have 2 operators working with him who draw the required stock and operate the unit as directed. Working on a rotating, triple shift system, the Sasol miners and operators work with the same mine crews day in and day out. They have effectively replaced the miner’s assistants that were previously employed and freed up the appointed section miner to concentrate on other areas of his work.

General

Blast designs were revised to accommodate the new explosives and detonators. The mechanized drilling increased the average hole size from 32 to 45mm and the round length from 2.0m to 4.0m. This allowed the number of holes in the faces to be reduced by an average of 32%.

Average face advance per blast of 93% have been achieved, and round lengths in excess of 4.2m are now the norm. Further trials to increase the round length to 6m are currently under investigation.

Initial costing exercises indicate that although more expensive products are being used, the down stream benefits result in a cheaper consumable cost per ton than were being realised with ANFO and capped fuse. Additional benefits to an improved mining cycle, cheaper drilling costs, reduced over break and better fragmentation also add to a better bottom line although some of these are difficult to quantify.

MINING LAYOUT AND SEQUENCE

Below are a few of the different methods, which exist, which may be used to mine the ore bodies of Amandelbult. Several of these methods have been implemented. The below summary is a brief description of how we experienced the mining methods.

Breast Scattered mining

- Currently 90% of our production on Merensky and UG2 reef horizons.
- Cost per ton varies, depending on the width of the seam, and the ground conditions, as well as depth below surface.
- Extensive development, construction, ledging, and equipping is required to prepare a stoping block.
- Extensive infrastructure of shafts, boxes and haulages, this also results in the ore being handled up to eight times between the stope face and the shaft silo.
- Distance of winch pull, 10 –100m, depending on the cross cut spacing
- Batch distribution, as the distance of pull increases, so the delivery of ore reduces.
- Labour intensive, current efficiencies average 42 centares per total stoping employee. The average per total employee costed for the mine is between 10 –11 centares per T. E.C.
- Restricted Mechanisation, due to in stope pillars, and A.S.G.'s
- Panel lengths vary from 15m to 40m, but the average is 34m.
- Dependency on machine operators
- Face advance limitations, due to free face limitations and handling of the broken rock.
- Continuous operations limitations due to re- entry time adherence.

- Lengthy time frame is required from holing of the raise until the stope is equipped and ready for a full stoping contract.
- Extensive development, construction, ledging, and equipping is required.

Breast retreat

- Certainty of ore reserves, but still a larger component of development is required.
- Extensive planning and pro-activity required
- Better face advance
- Ventilation difficulties
- Water controls
- Additional construction required
- Greater emphasis is required on development.
- Development costs need to be regained by additional production when stoping.
- Fire/water pillars lost.
- Roof bolts in A.S.G.'s become problematic
- Distance of winch pull, batch distribution
- Labour intensive
- Restricted mechanisation
- Dependency on machine operators
- Continuous operations limitations

Down dip mining

- Safer, drilling control is critical, as any off line drilling normally results in poor hanging wall conditions.
- Scraping distance may be from 10m to 200m.
- Reduced costs R100/ ton, throw blasting, tends to be effective, but blasts the support out if the opposite face is already stoped out.
- Extensive development is required before stoping starts.
- Each panel requires a tip, extensive box construction is required.
- No extensive ledging and equipping.
- Pulling of ore takes time and runaways are problematic, if the draw points are all situated in the haulage, should one box have a run away, then no tramming occurs in the haulage until the opened.

- Water control, tends to be difficult, and attempting to pump water and keep the scraper moving is almost impossible, unless up dip scraping occurs.
- Good face advance is normally achieved, as there is an established free face.

Long Hole stoping

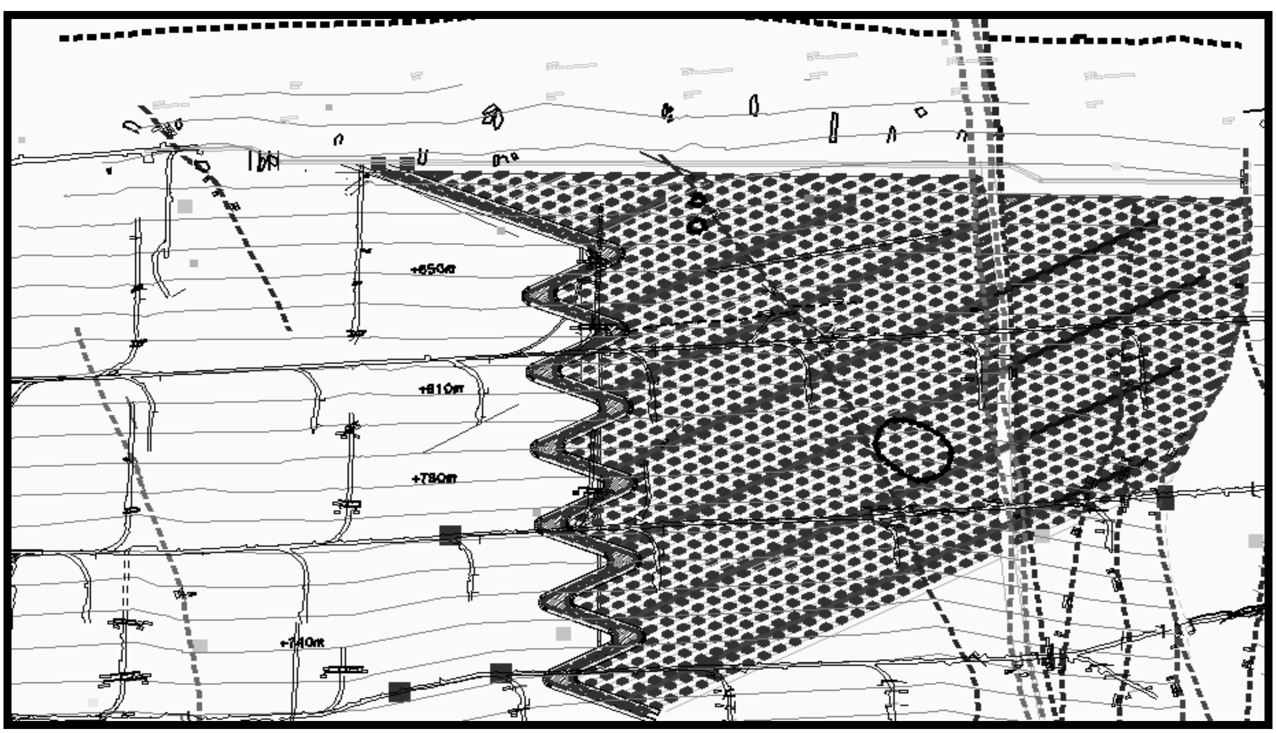
- Safety, Man-free stopes
- Reduced dilution, mine narrow seams profitably.
- Extensive mechanisation
- High skill levels required
- Shaft head cost of R87/ ton

Various alternative layouts for the 16W area.

Zigzag ramp with rooms and pillars, belt systems every fifth roadway.

- Extensive dilution
- Difficult zigzag ramp development.
- Belt management and installation probably impossible.
- Extensive truck usage might be the only alternative.

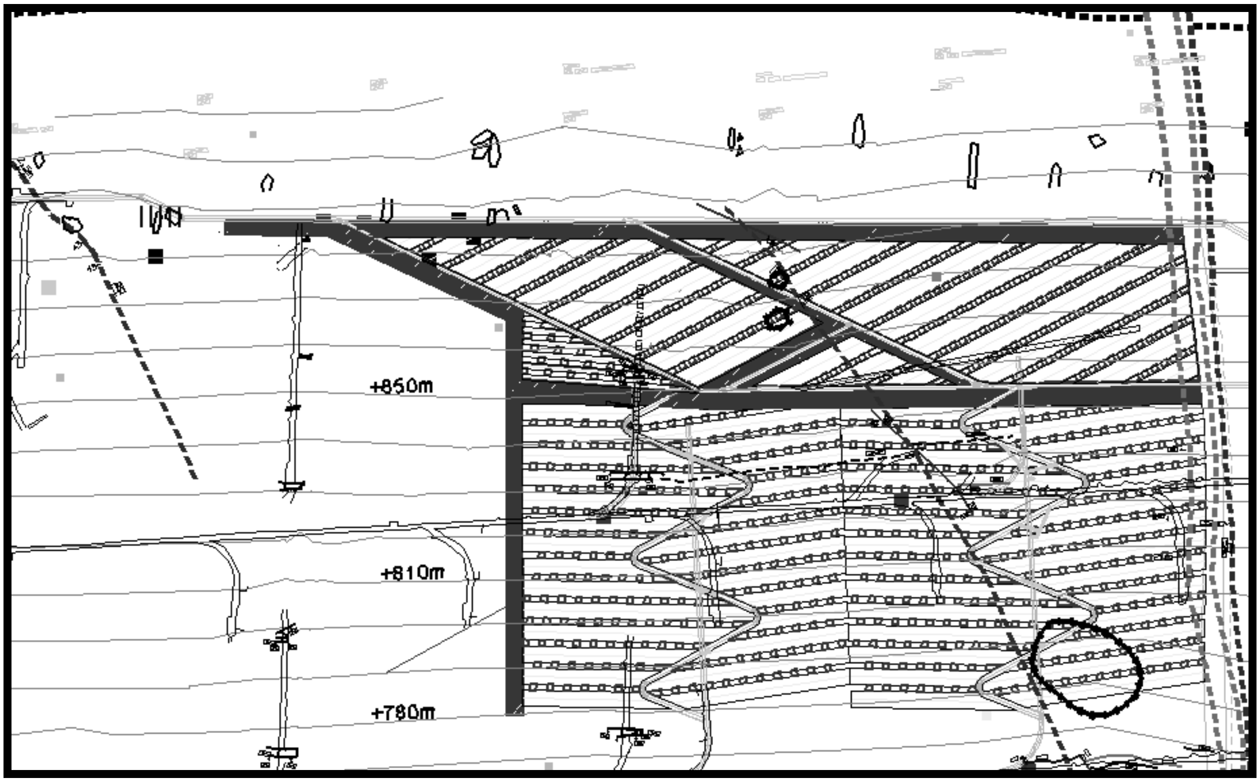
Figure 13- Zigzag room and pillar layout.



Combination of conventional panels and rooms, with LHD loading in the A.S.D.

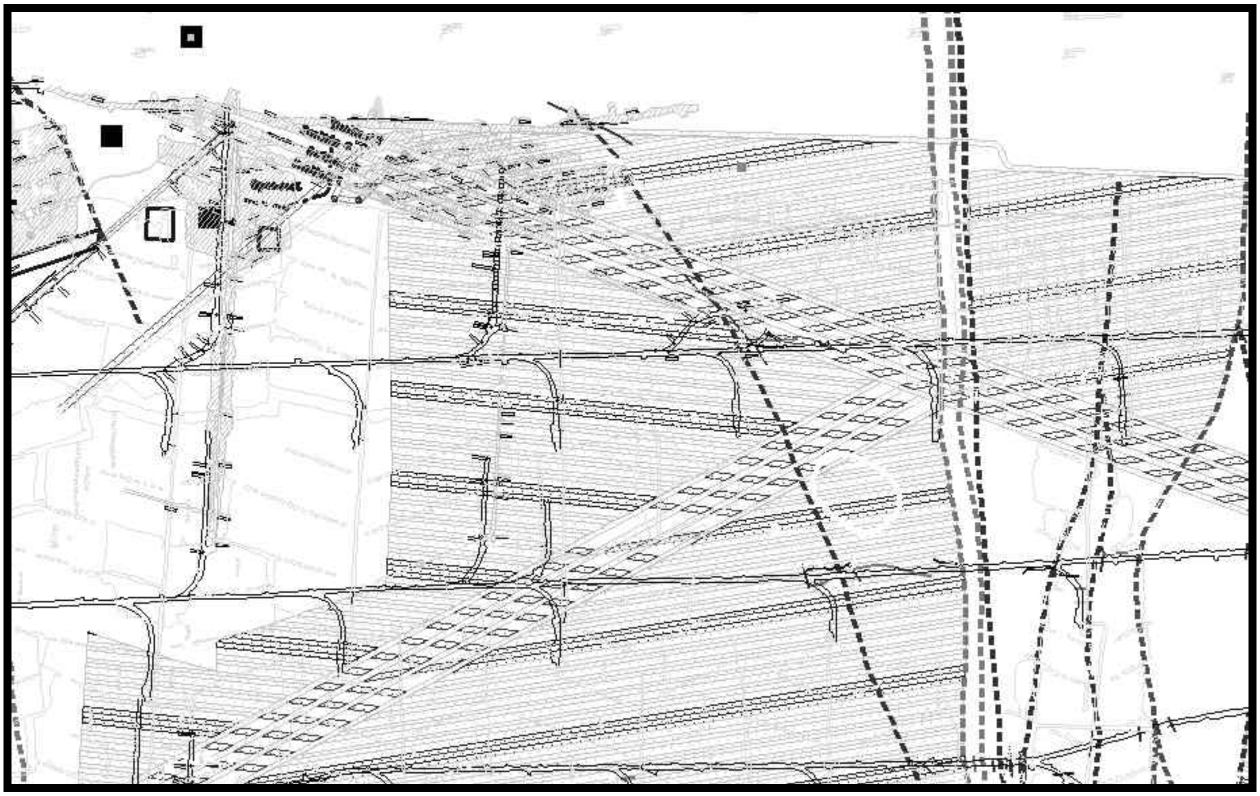
- Conventional panels extensively reduce the dilution, and the A.S.D.'s ensure that the " gully" is as ahead of the face, thus ensuring good face advance per blast.
- Difficult management of belts
- Difficult ramp development.

Figure 14- Combination of conventional / room and pillar.



The above two layouts are purely an example of how powerful the tool of CAD's mine is in looking at various mine designs for the same block of ground. It enables the mining engineer the ability to consider many different variations and critique each one until a desired layout is found.

Figure 15- The chosen design is seen below, adopted from Thorne cliff Chrome mine.



Access to the ore body

16w Decline

The decline was sunk as a means to gain a top holing position for the stopes, as the reef outcrops on surface, but there is a river course, which extends along a significant portion of the outcrop in this specific area. The decline was sunk outside the 100 year flood line, and then kept approximately 40-45m vertically below the surface, this ensured that the stopes had a holing point, allowing services access, men and material, as well as ventilation. The normal procedure would be to hole back to surface but this would have not been possible with out facing the risk of flooding the mine, during floods.

The decline was excavated until bedrock, where after it was blasted, into the bedrock, a ramp established, reinforced pre-cast concrete sections were then placed on a foundation, and then backfilling over the concrete sections took place, to reduce the catch-ment area, and stop weathering. The decline was then developed down at a nine-degree dip, until it reached 40m below surface, and then it was kept at this elevation below surface, and slightly below the reef plane for 1200m. When the room and pillar method was embarked upon, the decline was turned onto reef elevation, and then four declines were started down at nine at a dip of nine degrees, apparent to the reef, which dips at eighteen degrees.

8w Decline

This decline was started from surface as a means to provide fresh air, access to the mine for machines, but most importantly for the belt to come to surface and tip ore in the shaft silo. When laying out the position of the decline, the following had to be taken into cognizance:

- The position of the railway line, which determined the position of the surface silo.
- The position of the secondary national road, which is in the path of the belt.
- The position of the river and therefore the hundred-year flood line.
- The position of the Mined out Merensky opencast pit.
- The archaeological findings in the area
- The mined out Merensky stope, which the decline has to mine through.
- The middling between the existing declines, and the conventional UG2 stope.

Thus it was a significant challenge to find a way through all the above, below is a section of the decline, as it approaches holing into the mined out Merensky stope. The portal was excavated, thereafter it was drilled and blasted, and using a D.T.H. rig, and the ramp was blasted, there after the roadway established, a face was established and the first round taken to create a brow. Before the blasting of the brow and the decline occurred, pressure grouting was done to consolidate the ground, which is weathered and oxidized. Support work included the strapping and pinning of the brow with Osro straps and tensioned cables, the sidewalls of the portal were sloped and then pinned with mesh, lacing and shepherd crooks. The entire portal area was then covered with a layer of shot-crete, to stop weathering, and ensure the competency of the portal sidewalls. The surface area was minimized to ensure that it was not a significant catch-ment area for rainfall, it may still reduced by adding a reinforced roof, and then back filling the area.

The decline was then developed at nine degrees down, and stopped short of holing into the stope, at the same time development occurred from the bottom up, out of number two decline. The development holed into the old stope and support began to support the ramp as well as the brow. The support work, which took place, can be seen in the plan below.

The section below indicates the way in which the decline had to negotiate all the other excavations in the area, and yet still remain competent to be a long-term access to the area.

Figure 16-Section of 8W decline

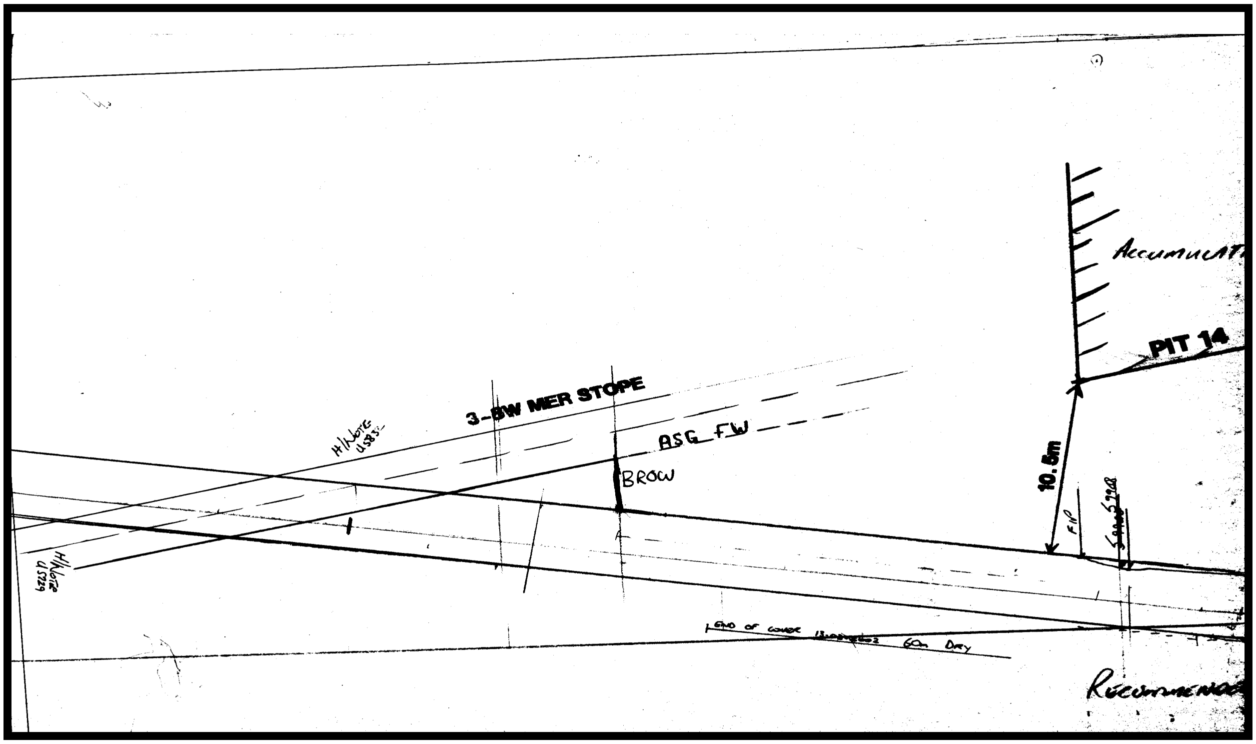


Figure 17- Plan view of the intersection of the old stope and the related support which had to be installed.

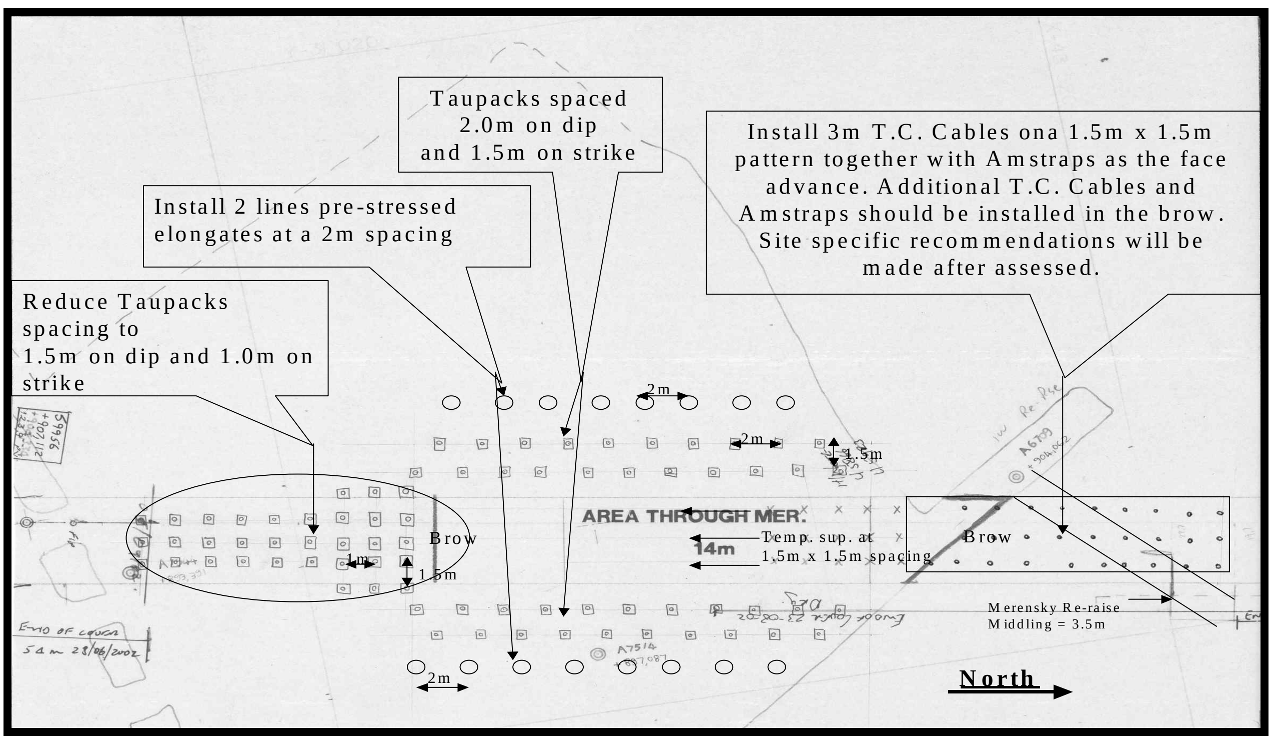
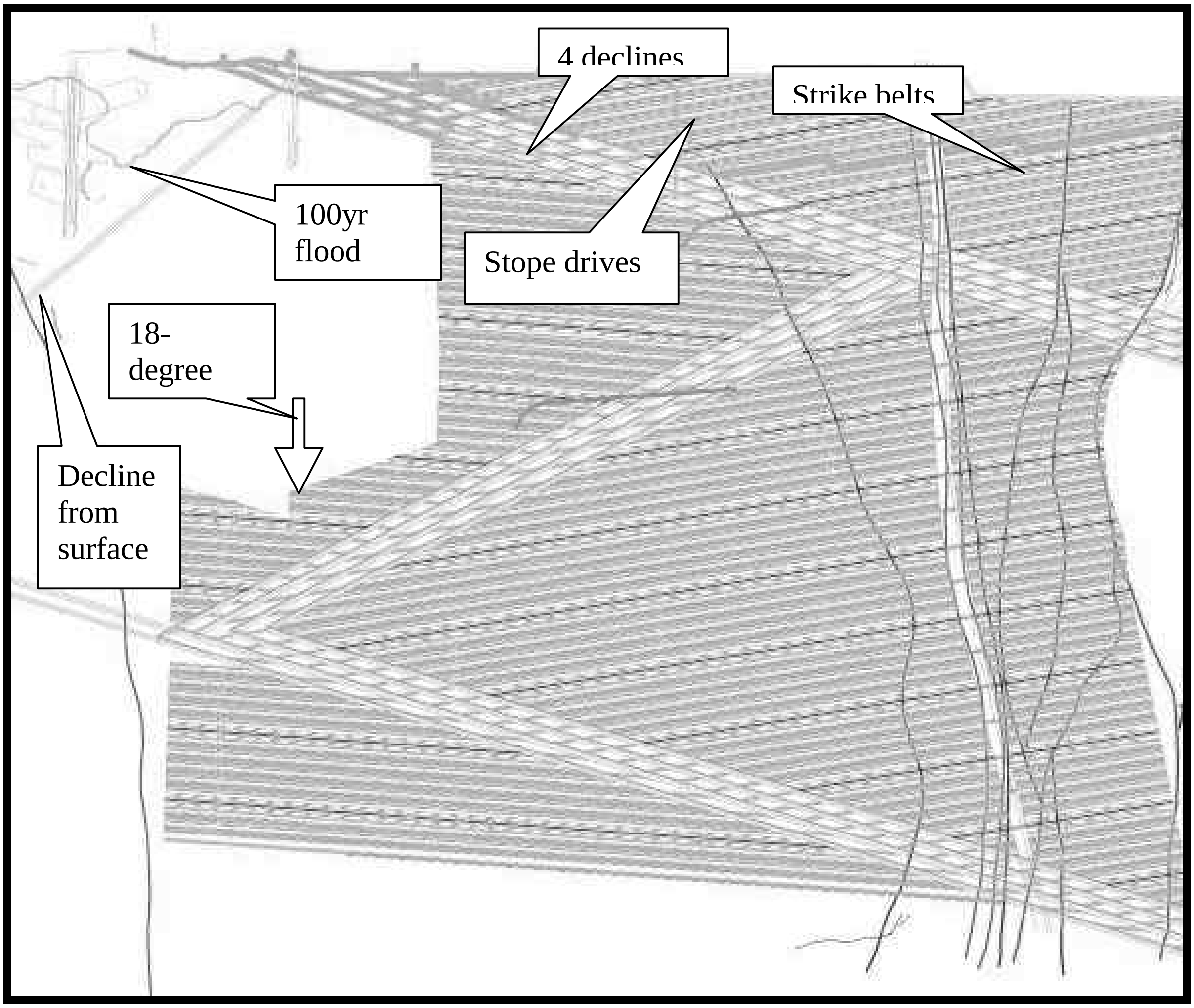


Plate 16- View down one of the ledging declines, going down on an apparent dip to the true dip, dipping at 9 degrees to vertical and at an average height of 1.8m.

How do you mine with trackless machinery at an 18-21 degree dip?

- Mining at an apparent dip
- Sweetening the pot, by taking ledges on reef out with the development, thereby creating squat pillars, which allows stability, but with less pillars, and a higher extraction rate.
- Pre-development, of the stope drives, and then sliping out the reef width only.
- Knowledge of UG2 from Merensky, has allowed us to achieve an extensive database of the UG2 reef horizon pre- production phase.
- The footwall of the Ug2 carries a value of 1 g/ton, thus allowing a lesser percentage of dilution.

Figure 18- Plan of 16W Mechanised mining area. The white block on the left is a layout for a conventional stope.



Drive four declines down at a 9-degree dip, one decline for ingress and the other for egress, the middle declines are equipped with a hanging wall belt, the other is an access and services decline. The outer declines are ledging declines, they are blasted at a reduced height, carry no services, and enable stopes to be started up, out of them without damaging any cables or pipes.

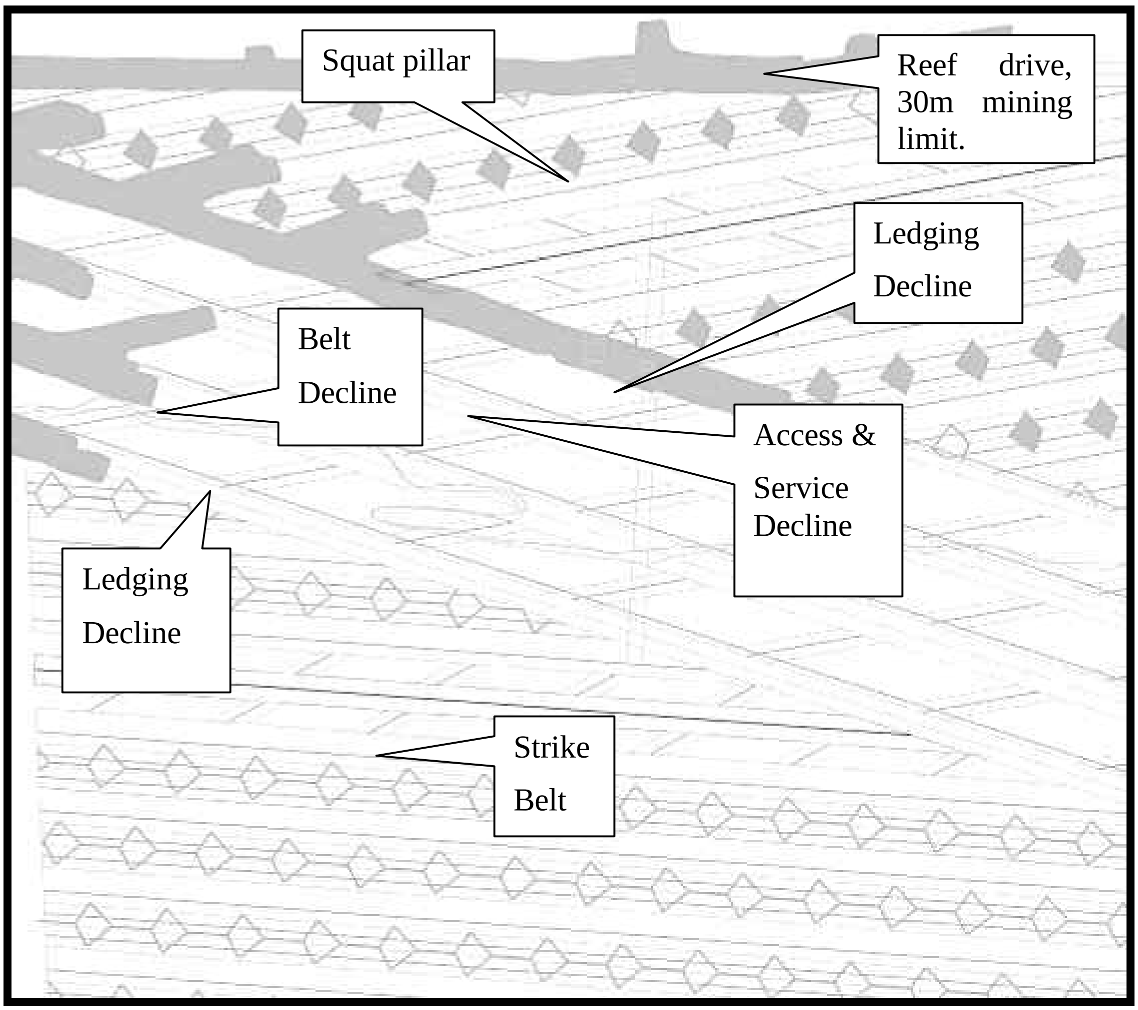
Follow behind hanging wall belt to be kept maximum 100m from the decline face, with all infra-structural services.

The outer declines serve as ledging declines, where the breakaway of drives will not effect or damage any of the infrastructures, as well as allow for separate vent districts.

Stope drives are at 5 degrees above strike and 2 degrees up, allowing water to run back from the face and be caught up and pumped from specific points. The footwall of all stopes will be at a dip of 12 degrees. Thus machines should never see the full 18 degrees dip, and should enable them to perform without slipping or getting stuck.

The stope drives will be driven to the end of the reserve, there- after 4m long-hole drilling will take place in the stopes. The drilling will begin from the back to the front, and blasting as well. This will ensure that person's work from a safe point, and that the high risk area, would not need to be accessed continually. The layout includes hanging wall belts, which are to be kept at a maximum of 100m from the face. The fishbone belt is on dip through three drives, this belt is a short belt, which tips on the strike conveyor belt. The strike conveyor carries the ore to the trunk conveyor, and the trunk/main conveyor carries the ore to the surface silo.

Figure 19- Micro layout of stopes, the dark areas indicating mined out areas.



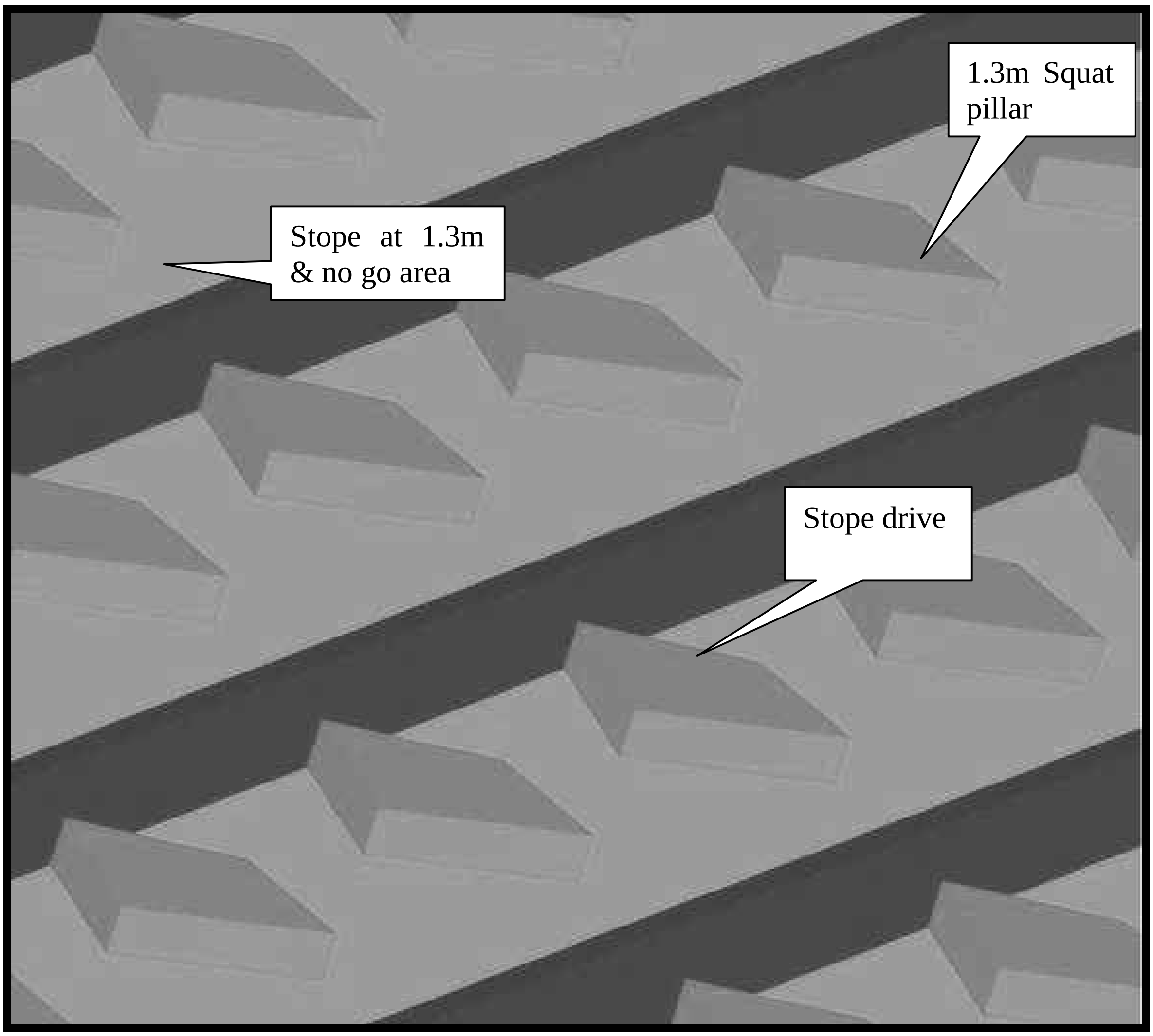
In summary:

- Drive the declines down at a nine-degree apparent dip.
- Drive four meter wide Stope Drives with a two-meter shoulder Reef Cut.
- Cut the footwall to create a 12-degree slope.
- Drive the stopes to end and then drill stopes on retreat
- Cut Pillars on Reef width - Squat pillar formula.

- Throw blast ore into roadway, and load.
- Vent holings are required every fifth holing
- Water-jet out no go zones
- Retreat vamping of roadways-stopes.

Ventilation holing's will have been blasted between panels during development phase, a holing will be blasted in the form of a wedge cut, and a minimum area of four square metres should be allowed.

Figure 20 -3D plans indicating the pillars and stoped out areas.



The long-hole stoping will then be throw blasted on retreat into the roadways.

Pillars will then be created at a normal 1.3m-stope width with improved strength using the squat pillar formula. The pillar strength is enhanced by reducing the width to height ratio, thus increasing the pillar strength, and improving the extraction rate.

Figure 21. – Section of ledging declines.

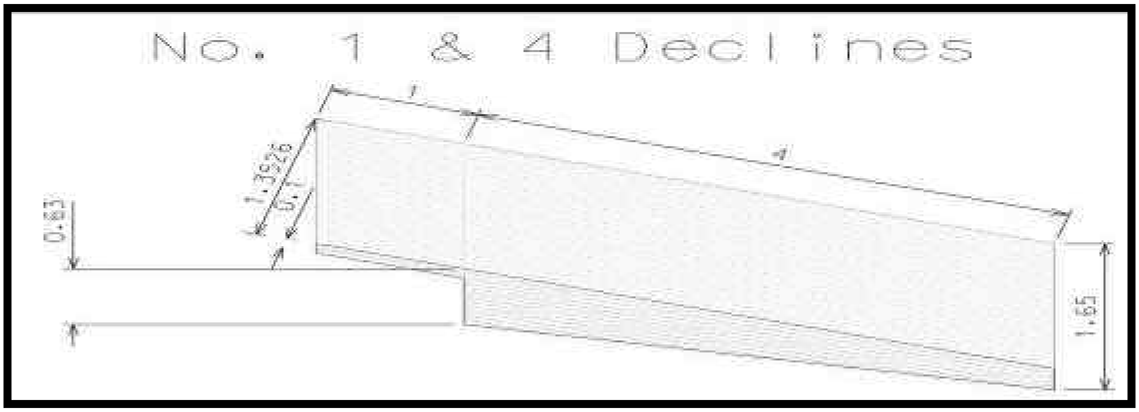
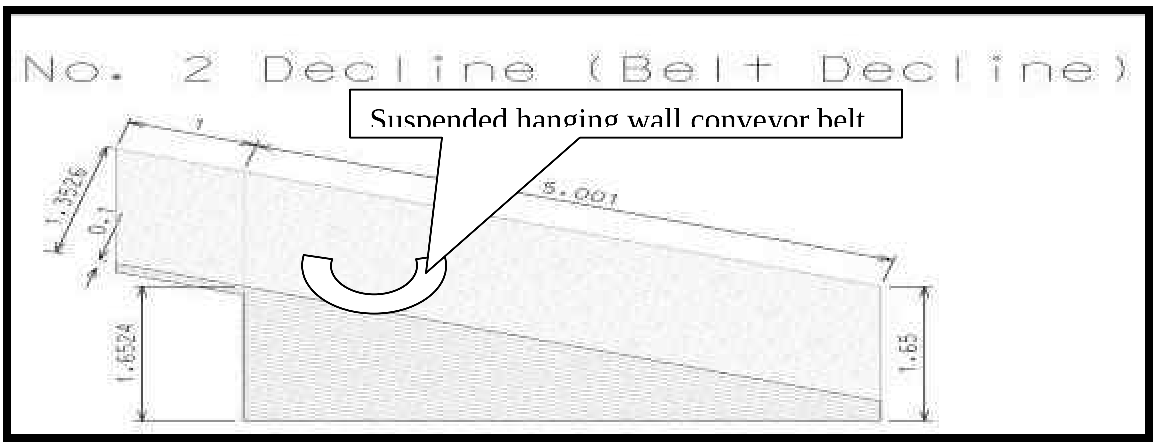


Figure 22. – Section of belt decline.



The installation of roof bolt support takes place in roadways during their development, using smart bolting techniques.

Pillar areas will be no go areas, once roadways have been long-hole blasted and cleaned.

Figure 23-Access and service decline dimensions

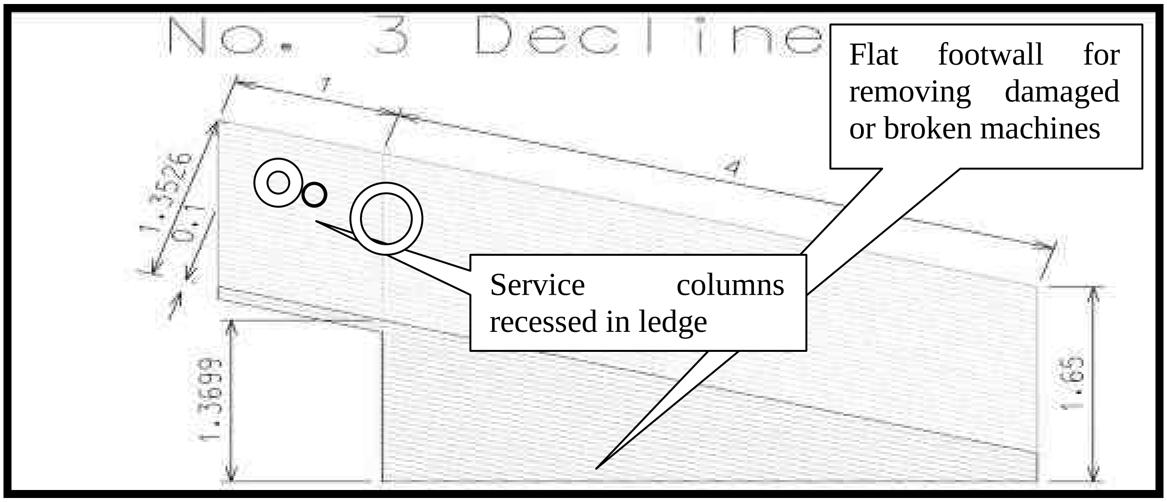
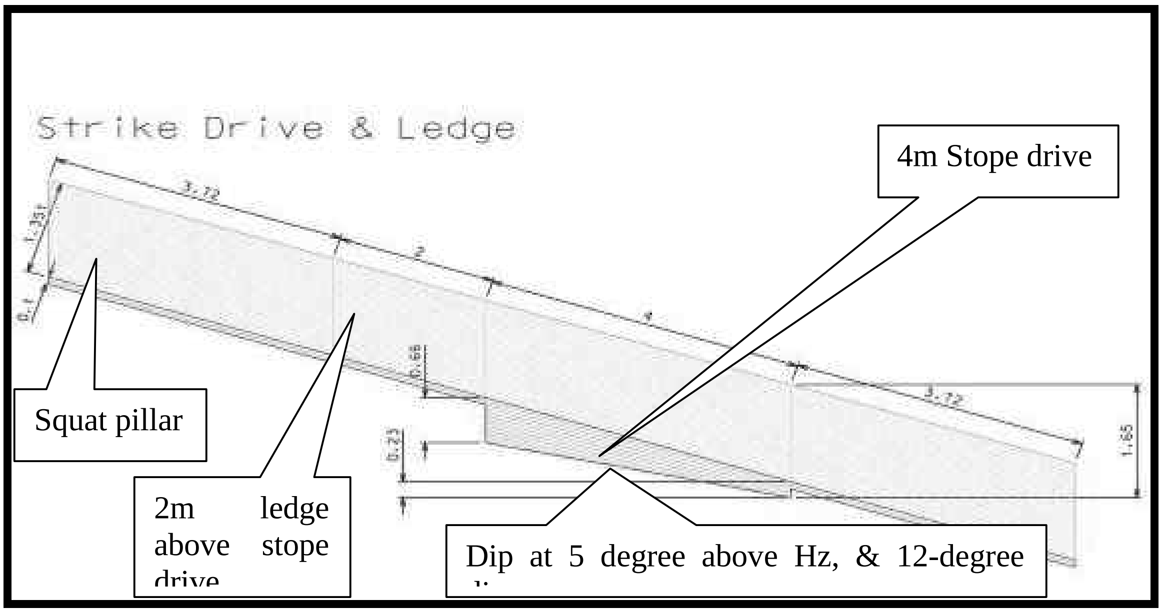


Figure 24- Stope drive section, with 2m shoulder.



The roadways will be LHD cleaned, thereafter water jetting will occur between roadways and then retreat vamping.

Ore will be transported by LHD's to a fishbone belt system.

VENTILATION

Design criteria

- Planned Tonnage — Build up to 60000 Tons per month.
- Quantity /1000 tons broken / month — 4,0 m3/s
- Ventilation quantity required for rock broken, 60 Kt/m x 4,0 m3/s equals 240,0 m3/s

Diesel Equipment

- 12 LHD’s @ 83 kW (100% utilisation) — 996 kw
- 7 utility Vehicles @ 63 kW (50% utilisation) — 220 kw
- 4 L.D.V.'s @ 85 kW (50% utilisation) — 170 kW
- 5 Drill Rigs @ 83 kW (30% utilisation) — 125 kW
- 3 Roof Bolters @ 63 kW (30% utilisation) — 57 kW
- 2 Graders @ 83 kW (30% utilisation) — 50 kW
- 1 Scalar @ 63 kW (30% utilisation) — 20 kW
- Total — 1638 kW

Ventilation quantity for exhaust emission

- Dilution @ 0,12m3/s per kW — 197,0 m3/s
- (Add 25% for leakage) — 246,0 m3/s
- Average Mining Depth — 340,0m below surface
- Virgin Rock Temp — 29,0°C
- Total heat added to the air by machinery (Diesel equipment, fans, conveyors and pumps) — Approx. 2300 KW

Cooling Requirements-

The current intake air temperatures and air quantities are sufficient to keep wet bulb temperatures below 26,0C.

Minimum quantities required for Development Declines and Stoping Drives

Development, one LHD operates in one development end at a time, thus the total kilowatts generated is 83kW. The ventilation required is therefore 10,0m³/s at 0,12m³s per kW. The method of ventilation is force ventilation, with 45kW fans fitted to 760mm vent columns, the minimum through ventilation quantity for four declines is thus 20,0m³/s.

Stope Drives, one L.H.D cleans a stope drive at a time, thus generating a total of 83kW, thus at 0,12m³/s per kW, 10,0m³/s. (Supplied up to the point of loading)

Ventilation of roadways and belt tunnel, during tipping operations and when vehicles are required to travel in roadways, through ventilation is provided for dilution of exhaust gasses. The minimum quantity required per decline at 1.5 m/s is 13,5m³/s, thus the quantity required for the four declines is 54,0m³/s.

Intake airways and Shafts

The existing belt decline (20,0 m2) and an additional decline (35,0 m2) from surface will supply 240,0 m3/s to the section. The intake airways cross-sectional areas were determined to ensure the belt decline velocity is maintained between 3,0 and 5,0 m/s. The above intake airways will be utilised for mining up to 5 level. A 4,5m diameter raise bored hole, down casting fresh air to 7 level will be required for mining below 5 level.

Main Fans

One twin stage axial flow fan with a duty of 100m3/s and static pressure of 3,5 kPa will be sited on top of a 12,0 m2 drop raised hole at the 2-west line. The existing two surface centrifugal fans in the 8-west area with a duty of 140 m3/s at a static pressure of 3,5 kPa will be utilised for the mechanised mining project.

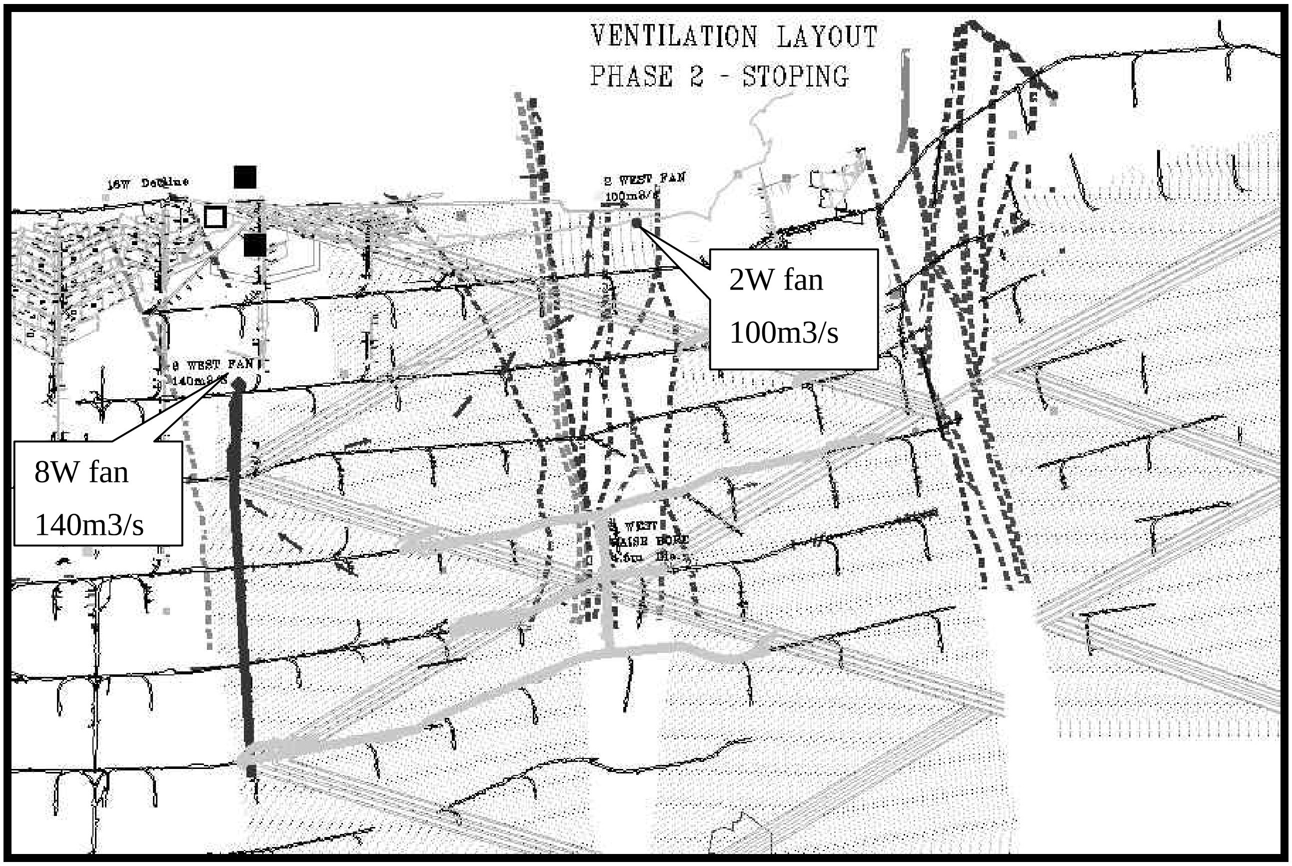
Production ventilation

The 16W mine has three ventilation districts, the decline development, and the east and west production sections. The production plans are to mine eight strike drives simultaneously on the east side and the same number on the west side. The ventilation distribution has been designed to minimise the installation of seals. Air jet fans are installed where required, to ensure that pollutants are removed and a constant supply of air is available at the face.

Escape and Rescue

Self-contained self-rescuers are provided to the workforce; in addition permanent refuge bays are established at predetermined positions. Personal Carbon Monoxide instruments are issued on a two per working area basis.

Figure 25-Ventilation Layout

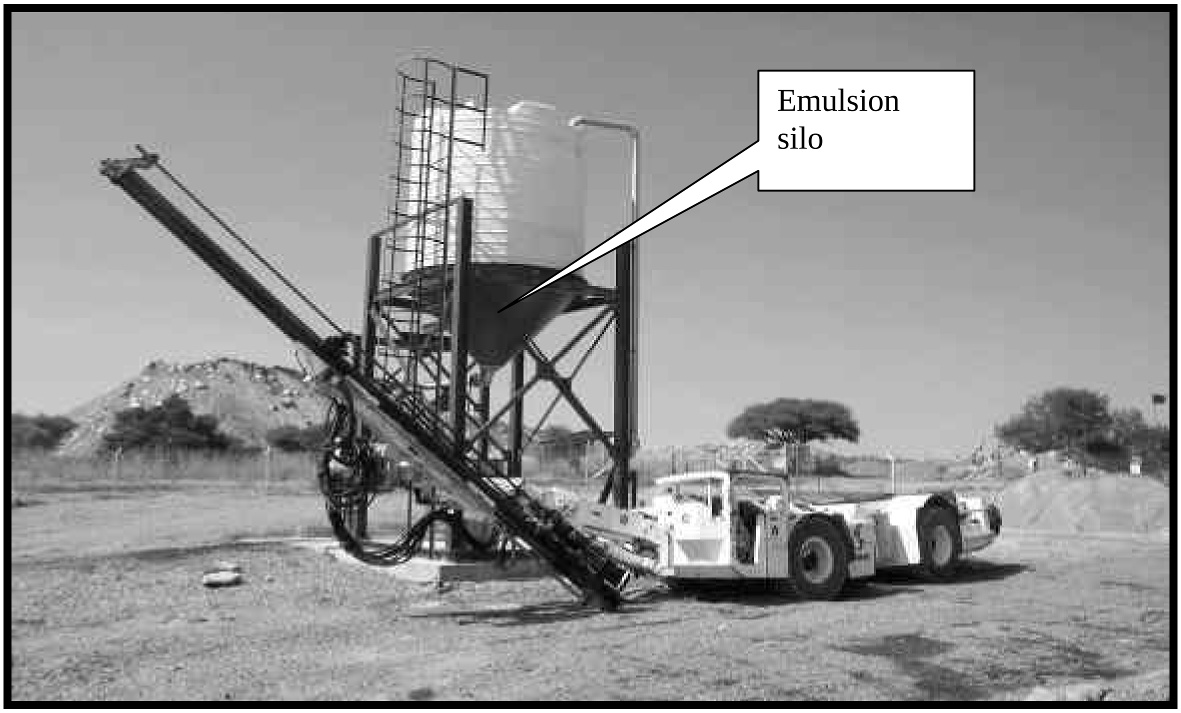


EFFICIENCIES AND COSTS

Anglo Platinum, just like most mining companies, is a seller in a commodity market, thus the main means it has to ensure its existence well into the future is to reduce its mining costs. The most significant manner, in which a seller can ensure it reduces its costs, is to increase its volumes. We cannot dictate our prices and thus remain price takers in a volume driven industry. Mechanisation is seen as one of the means of increasing output with the same amount of staff, thus only variable costs increase and fixed costs remain the same. Unit costs are positively affected though, and this results in the operation coming down the cost curve.

An LPD Aardmaster drill rig should deliver 25 000 tons, with three LP 4.2 Aardvarks supporting it. The fleet of equipment currently in use consists of the following:

Plate 16-Aardmaster 4.3m effective drilling boom, boom mounted on a 4.2 Aardvark chassis, in the background is the emulsion silo.



The fleet currently employed

Flexibility vs. mass moved per operator/ machine??
Discuss the merit in each of the above

Fleet for 25 000 tons per month.

- 2 x Aardmaster's (Drill Rig)
- 6 x Aardvark (L.H.D.)
- 2 x Utility vehicle (Transporter)
- 1 x Roof bolter (Support Drilling)
- 2 x Supervision Vehicle (4x4)
- 1 x Diesel & Lubrication Cassette
- 1x Low profile grader
- 1 x Emulsion Explosive Cassette

Fleet employed for 60 000 tons per month

- 2 x Aardmasters (Drill Rig)
- 6 x Aardvark (L.H.D.)
- 2 x Utility vehicle (Transporter)

- 1 x Roof bolter (Support Drilling)
- 2 x Supervision Vehicle (4x4)
- 1 x Diesel & Lubrication Cassette
- 1x Low profile grader
- 1 x Emulsion Explosive Cassette

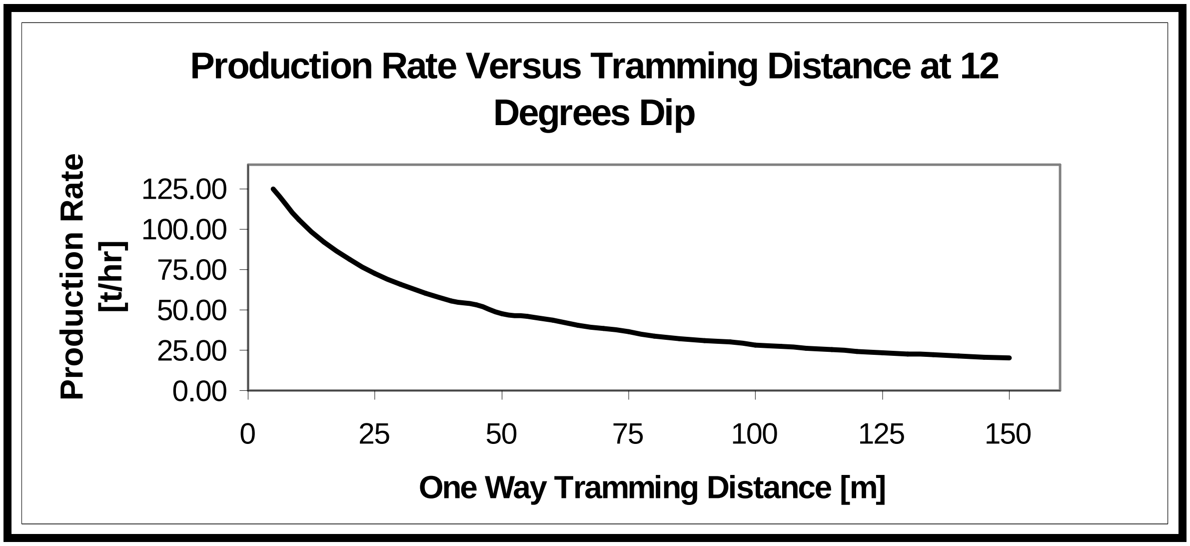
Plate 17- Low profile manual installation roof bolter, busy drilling a hole to install a resin bolt.

Table 4-Employee profile for 60 000 tons

UMO	1 Mine overseer	4 Shift supervisors	4 Miners	1 Foremen	5 Artisans	Total=15
MDP's	Supervisors- 1	Operators- 15	Belts- 15	LHD/ util- 28	Lash- 17	Total=76
Contractors	MRC- 8	Joe lee-3	SMX- 12	JIC-14		Total=37
Total employed						Total= 128

Employee efficiencies are expected to be a minimum of 300 tons per month per total employee costed.

Figure 26—L.H.D. Productivity



Foam filled tyres

Foam filled/ air filled tyre comparison.

The average wear life of a low profile LHD, is about 600 hours on the front, and 1000 hours on the rear, irrespective whether foam filled or not. This can obviously vary greatly depending on the working conditions and how the machine is operated. The advantage of foam filled tyres is that it eliminates downtime due to punctures, and tyres may used which have side wall cuts, driving on flat tyres is eradicated, tread damage is minimal and spinning of the rim within the tyre which is common at steep dips is also eradicated. Most wear and damage occurs on the front wheels as could be seen from the tyre life.

In summary tyre life is dependent on:

- Whether you fill it with air or nitrogen, nitrogen significantly increases tyre life due to reduced oxygen related deterioration.
- Roadways conditions, whether there are potholes, sharp rocks and water cause extensive tyre cuts, and an undulating roadway surface reduce tyre life extensively.
- Operator driving techniques, particularly when loading a muck pile, spinning the tyres causes extensive damage.
- Confined width of roadways and sharp corners, resulting in sidewall cuts, and the scrapping of air/ nitrogen filled tyres.
- Poor roadway sweeping after the blast, it is imperative that operators lash all fly dirt before entering the muck pile, note that the front tyre life is vastly reduced due muck pile loading and the weight of the bucket.

Facts with regard to foam filling.

- The mass of foam filled tyre is 150 kg per low profile tyre. (Fill is purchased per kilogram)
- Cost per tyre R 4500
- Cost per kilogram of foam fill= R 2300/ 150kg =
- Cost of puncture repair= R600
- Average down time = 1.5 hrs per puncture, up until foam filling began 132 punctures occurred resulting in, this equates to R. In lost revenue

Maintenance repair contract by supplier

To ensure that the machines receive the best maintenance possible, it was decided to involve the manufacturer, to maintain his own machines, the reason being he designed, built and understands the machine better than anybody else. The fact that the manufacturer is involved in the success of the project, made him a strategic partner, and thus forced him to take a long-term view of his product, and not just to complete a sale.

The contract is based upon a cost plus profit contract, where open books are kept, and the company pays a set amount monthly, this enables the contractor to make his money, and it stops the fight about engine hours and percussion hours. An availability clause though is worked in the contract to ensure that machines are continually available for production.

Table 5- Breakdown of costs YTD September 2002

MDP Employees	**102**
UMO Employees	**14**
Average Total Strength	**115**
YTD POMS	**15,591.49**
Profit / Tons Milled	**163.59**
Cost / Tons milled	**156.28**
Revenue / Tons milled	**319.86**
Cost / Ounces	**2,957.11**
Tons per Employee	**824.01**
Stores Cost per Ton	**31.96**
Sundry cost per ton	**51.63**
Utility cost per ton	**22.82**
Amortisation rate per ton	**33.18**

CONCEPTS AND PRINCIPLES

- No foot on the footwall
- 3 Cycle operations, continuous mining.
- Maximise Drill Rig capability, 4.3m to 6m rounds.
- Minimise tramming distance and handling
- L.H.D.’s in conjunction with conveyor belts.
- Handle ore once
- Rock on floor concept.
- Long hole drilling combined with throw blasting.
- Emulsion and E.D.D.’s.
- Maintenance Repair Contract- supplier
- Repairs and daily maintenance done at machine
- No go zones
- Clean mining
- Hot seat changeover
- Smart bolting / Spin to stall
- Three Cycle operations, continuous mining.
- Maximise Drill Rig capability, 4.3 meters.
- Minimise tramming distance and handling
- L.H.D.’s in conjunction with conveyor belts.
- Handle ore once
- Rock on floor concept (SMX).
- Long hole drilling and Throw blasting.
- Emulsion and E.D.D.’s.
- Maintenance Repair Contract- supplier
- Repairs and daily maintenance done at machine
- Canopy protection, no foot on footwall
- No go zones
- Clean mining
- Hot seat change-over
- Smart bolting / Spin to stall

FUTURE FRONTIERS

To reduce injury ratio's

To reduce costs to R65/ton - shaft head cost

To increase productivity to 500 tons per TEC

To control dilution

To improve our planned maintenance systems

Retention of skills and correct training

Managing the life expectancy of machines

Dealing with geological anomalies

Managing the Rand / Dollar exchange rate exposure, as most machines have a minimum of 60% imported parts and components.

The challenge, which lies ahead for us, is to Prove the viability of Amandelbult's room and pillar mining using the above method, whilst setting a benchmark for the industry to compete against.

CONCLUSION

We believe that it is possible to mine a reef at 18-21 degrees, using trackless machinery. The mining method is not a simple mining method, and requires high levels of skill and discipline; supervision plays a key role as any mismanaged issue results in risk being increased. The biggest challenge that lies ahead is proving that the above theory can be practically applied, as well as achieving the key performance indicators.

I would like to thank the management of Anglo Platinum, Amandelbult and my dedicated team for allowing me to present this paper on their behalf.

REFERENCES

Acknowledgement must be given to all those who contributed to the input of this paper:

Mr. F Uys	Mine design and overall input
Mr. M Roebert	
Mr. A Opperman	Mine and machine design
Mr. Q Snyman	
Mr. K Theron	Geological report and overview.
Mr. N Nel	Dilution, layouts and survey
Mr. J van Eyssen	Ventilation layouts and input
Mr. P Altouyan	Smart bolting
Mr. K Ackerman	Rock Mechanics
Mr. H Frey	Rock mechanics
Mr. A Bezuidenhout	Engineering inputs
Mr. D Biddle	Engineering inputs
Mr. B Brown	Explosives
Mr. H Spamer	Personnel inputs.